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"More caulking and less talking"—Mrs. Schwab's motto for shipbuilders

SCENES IN A SHIPYARD [See page 104]

The Nitrogen Problem in Relation to the War*

Resources and Methods for Making Materials Required for Explosives

By Arthur A. Noyes[1]

THE subject with which I am to deal is so vast that it is impracticable to present more than a brief survey of it. I shall not attempt to go into technical details, but shall rather attempt to give you a general view of the situation, and a brief description of the various methods we have for meeting the demand for nitrogen compounds and of the principles which are involved in those methods.

You all realize the vital importance of an adequate supply of nitrogen compounds, particularly of nitric acid and ammonia, in ensuring our success in this war. From nitric acid are made all the important explosives such as smokeless powder, picric acid, ordinary black powder, dynamite, trinitrotoluol, and ammonium nitrate. This last has recently come into the greatest prominence as one of the most important and valuable of our explosives. In fact, it is reported that the Minister of Munitions of England has said that this war must be won with ammonium nitrate, as no other explosive can be produced in quantity adequate to meet the enormous demands of the Allied armies in Europe. This development of the use of ammonium nitrate has brought about a heavy demand for ammonia. In the early stages of the war it was anticipated that what we must look out for was an adequate supply of nitric acid, but at the present time we are no less interested in a sufficient supply of ammonia.

Let me briefly recall to you what are our sources of these two nitrogen compounds.

Our first source is Chile saltpeter, or sodium nitrate, which is found in a natural state in the dry regions of Chile, and which, until recently, furnished the total supply of nitric acid of the world. We depend for our own nitric acid supply upon the imports of Chile saltpeter into this country, which is a rather precarious source. In the first place, we are dependent on adequate shipping, and ships are scarce. In the second place, there has always been danger that enemy machinations, through interfering with production, destroying the plants, or blowing up the oil supply used for fuel, would reduce the production, or that our supply might be cut off entirely, by the establishment of a submarine base on the Pacific Coast. All of these possibilities make it unsafe to rely for our nitric acid supply on Chile saltpeter alone. But, even if none of these results actually came about, it would still be impracticable to get the huge amount of nitric acid that is going to be needed for the American Army through imports of Chile saltpeter.

Our second source is the ammonia from the by-product gas and coke ovens—the ovens, that is to say, in which coal is heated to produce gas or coke. We have, as I shall describe later, a well developed process for the conversion of ammonia into nitric acid, so that if we get from any source an adequate supply of ammonia, we can convert in into nitric acid. I shall not enter at any length into the production of ammonia from gas and coke ovens. I will recall to you briefly that for a long time, until within say ten years, this country was producing most of its coke in the so-called "bee-hive" oven, which is simply a hemispherical kiln. The coal is charged into the oven and set on fire, and the products of the combustion are allowed to pass into the air, so that the ammonia and valuable hydrocarbons that might have been obtained are lost. During the last decade, and especially during the last few years, there has been a very rapid introduction of the so-called by-product ovens, in which the coal is heated in closed retorts and the gases are passed through condensers and scrubbers by which the hydrocarbons and the ammonia are recovered. It was alleged by some of those representing the by-product industries that this supply of ammonia would alone suffice to meet the military needs of the Government; but the result has proved that it is utterly inadequate. Even if we produced all of our coke in by-product ovens, the supply would be far from sufficient. Of course, the Government is interested in extending the introduction of by-product ovens as rapidly as possible; but the by-product industry is tied up with the steel industry. It is mainly in the metallurgy of steel that coke finds its use, and we can produce ammonia only in proportion as there is a demand for coke. It is true that in Germany, where in the early stages of the war the need for hydrocarbons was very acute, coal was coked extensively just for its ammonia and hydrocarbons, and great quantities of coke were piled up, to be used after the war. Our Government has not yet felt that our needs warrant such extreme action as this, as the value tied up in the coke is large compared to the value of the by-products, and the difficulties of securing deliveries are serious.

Our third source of these nitrogen compounds is atmospheric nitrogen. During the last fifteen years there have been developed a number of chemical processes by which the nitrogen of the air is "fixed," as we say, whereby ammonia, nitric acid, or sodium cyanide are produced. I wish particularly to speak of the four most important processes which have been operated on a commercial scale. These are the cyanamide process, the cyanide process, the arc process, and the synthetic process.

Let me briefly describe to you the principles involved in these different chemical processes. I shall endeavor to show you what materials are needed and how far power enters as a factor.

1. In the *cyanamide process* we start with lime and powdered coke. The first chemical reaction that takes place results in the formation of calcium carbide, as follows:

$$CaO+3C=CaC_2+CO.$$

This is the substance which is used so extensively in the manufacture of acetylene for oxy-acetylene welding. The carbon monoxide escapes as a gas. This first step in the cyanamide process is carried out in huge electric furnaces. The charge of lime and coke in small lumps is fed down through the furnace in the center of which stands a large carbon electrode. The walls of the furnace form the other electrode. The mixture is heated to a very high temperature, and the melted carbide is tapped off at the bottom from time to time and allowed to solidify.

The carbide is then crushed and subjected to the nitrifying process. Namely, it is packed into large basket-shaped containers 3 to 6 feet high and 2 to 3 feet in diameter, which are enclosed in an iron vessel supplied with nitrogen. The basket has holes through the sides, and down the center runs a resistance wire. The reaction is started electrically by heat produced by passing a current through the wire. The reaction which takes place is as follows:

$$CaC_2+N_2=CaCN_2+C.$$

This gives us a product properly called "calcium cyanamide" which contains some unchanged carbide (about 3 per cent), and some lime and carbon.

The cyanamide process was the only one of the fixation processes which was being operated on any considerable scale in this country when we entered the war, and which is being so operated now. There is a plant operated by the American Cyanamid Company at Niagara Falls, Canada, which has been producing something like 20,000 tons of cyanamide a year. The product has been used to a limited extent in agriculture, but unfortunately the large amount of lime which it contains prevents it from being so used in unlimited quantities.

For the production of ammonia the cyanamide has to be treated with steam, whereby the following reaction takes place:

$$CaCN_2+3H_2O=CaCO_3+2NH_3.$$

This process is carried out in huge autoclaves about 20 or 30 feet high and 4 to 6 feet in diameter. The powdered cyanamide is fed into an alkaline solution and then steam is blown in; the mass is heated, the reaction begins and becomes violent, and the ammonia is allowed to collect up to a pressure of 12 to 15 atmospheres, when it is blown off. Then, after the reaction has spent itself, the residue is again charged with steam so as to get a complete removal of ammonia. When carried out properly, it is practicable to get substantially all of the original nitrogen in the form of ammonia. This gives ammonia free from organic matter, except that it contains some acetylene, coming from the calcium carbide present.

2. I speak next of the *cyanide process*, in which the reaction that takes place is, in its net result, as follows:

$$Na_2CO_3+4C+N_2=2NaCN+3CO.$$

A mixture of soda-ash with finely powdered coke and iron is heated at about 1,000° C. in nitrogen gas. There is a considerable conversion of the sodium carbonate into sodium cyanide, with evolution of carbon monoxide. The iron acts simply as a catalytic agent. This operation is carried out in a number of different ways. In one of the forms of furnace, so-called "briquets," which are really pencils made by moistening the mixture and squirting it through a die, are fed down through a long tube 8 or 10 feet high, which is heated on the outside by flue gases from the combustion of coal. The heating gases pass around the outside of the tube. The charge feeds slowly down through the heated zone and is drawn out from time to time by a special device at the bottom.

As in the case of cyanamide, so in this case also, to get ammonia we have to treat the product with steam. If we treat it at a low temperature the cyanide gives ammonia and sodium formate:

$$NaCN+2H_2O=HCOONa+NH_3.$$

When the formate is heated it breaks up, yielding sodium carbonate:

$$2HCOONa=Na_2CO_3+CO+H_2.$$

Thus the sodium carbonate used in the process is regenerated. Really, all that is consumed is the carbon, and the nitrogen taken from the air.

The nitrogen used in both of the processes just described is obtained ordinarily from liquid air by one of the familiar liquefaction and distillation processes.

It will be noted that the cyanide process accomplishes in a single operation a result which requires two operations in the cyanamide process. By using soda instead of lime, we combine the two steps (conversion of lime to carbide and of carbide to cyanamide) into one. The final steaming is the same in both processes.

3. The *synthetic process* is an extremely simple one chemically, involving the following reaction:

$$N_2+3H_2=2NH_3.$$

There is a rather interesting history connected with this. The proportion of ammonia which forms from the elements (hydrogen and nitrogen) at atmospheric pressure at any temperature where the rate is rapid enough so that it will form within a reasonable time is extremely small. The proportions (by volume) of ammonia at various temperatures and pressures that are present when a mixture of three volumes of hydrogen and one of nitrogen reaches equilibrium are shown in the table:

	1 ATM.	100 ATM.	200 ATM.
degrees	*per cent*	*per cent*	*per cent*
500	0.13	10.7	18.1
600	0.05	4.5	8.3
700	0.02	2.1	4.1

Thus at 500° we find, from the laboratory investigations that have been made on the equilibrium of this reaction, that there is only 0.13 per cent of the nitrogen converted into ammonia when the mixed gases are at atmospheric pressure, whereas at 200 atmospheres there is 18.1 per cent. As the temperatures rises the result is much less favorable. At 600° we get only 0.05 per cent, and at 700° 0.02 per cent, at atmospheric pressure. These unfavorable equilibrium conditions of the reaction, and the known fact that its rate is very slight until the temperature gets high, led to the belief that there was no hope of the development of this reaction into a technical process. However, a German chemist, Haber, demonstrated, by working at high pressures and at the same time at the low temperatures made possible by the discovery of a good catalyst, that this reaction can be carried out on a commercial scale, and this is in fact being done very extensively in Germany.

4. Finally, we have the *arc process*, which, like the synthetic process, involves an extremely simple chemical reaction:

$$N_2+O_2=2NO.$$

At a very high temperature nitrogen and oxygen unite to form nitric oxide. In this case the effect of temperature on the equilibrium is exactly the opposite of its effect on the ammonia equilibrium. The higher the temperature, the more nitric oxide is obtained; but there is very little until the temperature becomes very high. At 1,600°, 0.4 per cent (by volume) of a mixture of equal parts nitrogen and oxygen is converted into nitric oxide; at 1,900°, 1.0 per cent; and at 2,400°, 2.2 per cent. It is clear, then, that we can get a considerable production of nitric oxide only by operating at a high temperature. But not only is it necessary to operate at a high temperature, but the gases must be cooled so quickly that in the process of cooling the reaction does not go back again. The gas must be cooled rapidly to such a temperature that the *rate* of decomposition of nitric oxide into oxygen and nitrogen is made very small. The only really practical way in which this can now be carried out is by using an electric arc. An arc produces locally an extremely high temperature, and the gas can be drawn rapidly away from the arc and quickly cooled.

Before describing the ways in which this reaction is carried out commercially, I shall first call attention to the remaining reactions which are involved in the production

*Report of a lecture given before a joint meeting of the Washington Academy of Sciences and the Chemical Society of Washington. Reproduced from the *Journal of the Washington Academy of Sciences*.

[1]Massachusetts Institute of Technology; Chairman of the Committee on Nitrate Investigations, National Research Council.

of nitric acid by the arc process. The nitric oxide, when the gas cools to below 150°, combines with oxygen to form nitrogen peroxide:

$$2NO_2+O=2NO_2.$$

This reaction does not take place instantly and time must be allowed for its completion. The peroxide is then treated with water, three molecules of it forming two molecules of nitric acid and regenerating one of NO. The first reaction has again to produce more NO_2 before the next step can take place, and the fact that these reactions must go on successively explains the great difficulty in absorbing these nitric vapors in the absorption towers.

Two of the forms of furnace used may be briefly described. The essence of them all is to form an arc which will have a very large surface so that the gas will be brought into contact with the high temperature and will then cool off very rapidly. Various devices have been used for spreading the arc. The Birkeland-Eyde process, which is the one most used in Norway, uses an electro-magnet. If a magnet is placed at right angles to the arc, the well-known deflection of the electrified particles or electrons passing from one electrode to the other is produced, and thus the arc is drawn out into a disk-shaped flame. Another process for spreading the arc is known as the "Pauling process," an Austrian process, for which a small installation has been erected in this country at Nitrolee, South Carolina. The electrodes are water-cooled metal pipes. The arc forms between them and a blast of air spreads out the arc into the wider portion between the electrodes.

The arc process, when carried out in the manner described, consumes a very large quantity of electric power, and it is interesting to know where that power goes, because in this direction lies the main possibility of substantially improving the process. Of the electric power that is put into the arc only very little (3 or 4 per cent) is consumed in causing the union of nitrogen and oxygen to form nitric oxide. The rest of it is used merely for heating the entering gases from a comparatively low temperature up to the temperature of the arc. Only by devising an adequate preheating system, by which the outgoing gases heat to a fairly high temperature the incoming air, can we hope to increase very greatly the efficiency of the arc process.

Before reviewing the economic status of these different processes and their relation to our needs in the war, I wish to call your attention to one other chemical process, namely, the conversion of ammonia into nitric acid. If we are going to fix nitrogen as ammonia by either of the first three processes, we must convert it into nitric acid, and this is done by the following very simple chemical reaction with the aid of platinum gauze as catalyst:

$$4NH_3+5O_2=4NO+6H_2O.$$

Ostwald, some twenty-five years ago, discovered that, when a mixture of air and ammonia is passed over platinum and certain other catalyzers, there is an oxidation of the ammonia in large measure to nitric oxide, which, when the gases are cooled and brought into contact with oxygen and water, goes through the two reactions that have already been described, and nitric acid is produced. This process has been perfected so that it is now a very valuable means for getting nitric acid from ammonia.

Let me now review the situation as to the development of these processes. The cyanamide process uses materials that are nearly universally available: limestone, coke, and nitrogen from the air. The limestone must be of good quality and free from magnesia to work satisfactorily, but there are abundant deposits all over the world of suitable limestone. It uses a moderate quantity of power; this is used especially in the first stage of the process, in the production of the calcium carbide. So, as a result of these conditions—the small amount of power and the availability of the materials—this process has been installed all over the world.

The synthetic process, which had been pretty well developed in Germany before the war, and which has undoubtedly been much improved since, had fortunately been worked upon in this country by the General Chemical Company, and shortly after this country declared war, the company offered to the Government the use of its synthetic process for the production of ammonia. The company stated that they had so far perfected the process—well beyond the point which the Germans had reached before the European war—that they were able to operate at a temperature of about 500° and at a pressure not exceeding 100 atmospheres. The Germans, before the war, were operating at nearer 200 atmospheres and at a considerably higher temperature; and, as we have seen, higher pressures and higher temperatures both add to the difficulties of the process. The Government accepted the offer of the General Chemical Company, and as a result of it a plant is being built to operate this process at Sheffield, Alabama, which will have an output of about 20,000 tons of ammonium nitrate per year. The ammonia produced will be put through the oxidation reaction, converting it into nitric acid, and combined with more ammonia, because ammonium nitrate is the one thing which is needed in very large quantities at the present time.

The arc process would seem especially suitable for the production of nitric acid, as it is as simple as it can be chemically. The installation is somewhat expensive, but the really serious objection to it, particularly under American conditions, is the very large amount of power that is required. While the cyanamide process uses 2.2 horse-power-years per ton of nitrogen, the arc process uses nearer 10 horse-power-years. It can be economical, therefore, only where very cheap power is available. In Norway, where power costs about four dollars per horse-power-year, this arc process is being carried out on a very large scale, and the nitric acid is being sold partly to Germany, but mainly to the Allies.[3] In this country not only would the cost be very great because of the large power requirement, but power is not available that we can afford to devote to the process. There is a great scarcity of power in the eastern sections of the country even for the very necessary industries, and while there may be certain cheap powers on the Pacific coast, we have no ammonia there, as coke is not being produced; and we cannot therefore carry out the arc process in the Far West because we would not be able to ship the product in solid form. The arc process in its present form, therefore, does not look promising for use in this emergency; but if it could be perfected by a 50 per cent reduction in the power requirement, it would at once become an extremely valuable process. The arc process, I may add, is available in this country, all details being well known, so that if it were not for this power difficulty it could easily be installed.

There is also developing in this country, as a result of the investigations of Prof. J. E. Bucher, of Brown University, the cyanide process, which I have already described. The chemical reaction involved in it was well known, and the use of iron as a catalyzer had also been discovered; but the first attempt to put the process on a commercial basis was made by the Nitrogen Products Company, which has built a small cyanide plant near the Mathieson Alkali Works, at Saltville, Va., where nitrogen is available from the ammonia-soda process. The Government is also building a plant to operate this process under the rights which the Company has given to it. The Bureau of Mines is constructing this plant, which will produce 15 tons of sodium cyanide per day. Sodium cyanide itself is important; in fact, it is so valuable that it will not pay to convert it into ammonia until the market for cyanide has been satisfied; and it is also of some use in poison-gas work. Still, the use of cyanide is limited in gas warfare, and the demand for this purpose is not great.

Another company, the Air Reduction Company, has also worked out a cyanide process on a similar principle, and is prepared to make cyanide on a commercial scale.

Although this process has been put on a semi-industrial basis for the production of cyanide, the next step in it—the steaming of the cyanide for the production of ammonia—is still in the experimental stage. There is no doubt that ammonia can be liberated almost quantitatively by proper steaming, and it is only a question of time when it can be worked on a commercial basis. The Government has no plant for the production of ammonia from cyanide, but it has installed a small plant in Rhode Island for the experimental production of ammonia, in cooperation with the Nitrogen Products Company.

The Government, as I have said, is building a synthetic process plant with a capacity of 20,000 tons of ammonium nitrate a year at Sheffield, Alabama (U. S. Nitrate Plant No. 1). It is also building a cyanamide process plant with a capacity of 110,000 tons of ammonium nitrate at Muscle Shoals, Alabama (U. S. Nitrate Plant No. 2). And a third plant has been authorized for the production of another 110,000 tons of ammonium nitrate per year. It is to be located in Ohio, half of it at Toledo and half at Elizabethtown. It is hoped that the synthetic process in the first mentioned plant will be under way in the course of two or three months and that it may then be assured of success, so that the Government will be able to extend the synthetic plants. It is possible, also, that the cyanide process and the arc process may be developed so that they can be utilized.

Regarding the relative economies of the different processes, it is difficult to say anything very definite. It is clear, however, that the arc process in its present inefficient form is excluded, with power at the high cost that it has when it must be produced from coal. The arc process might be operated in competition with the other processes if power could be obtained at, say, $10 or $12 per horse-power-year. The cyanamide process has the advantage that it can be installed in many places in this country and that it requires little power. The cyanide process has a similar advantage in that it, also, requires materials which are readily obtainable—soda ash, carbon, and the nitrogen of the air—and requires no electric power. While we have no very definite information as yet as to the relative costs of producing ammonia by the cyanamide and the synthetic processes, the estimates of those who have developed the latter and the reports that have come from Germany have indicated that the cost of production by the synthetic process in normal times will be very considerably less than that by the cyanamide process. It is true that the synthetic process involves high pressures requiring special machinery, but the other elements in it are more favorable.

The hydrogen that is required in the synthetic process is one of its large elements of cost. It is, therefore, important to get a cheap method for the production of hydrogen. The general method which has been adopted in Germany is to reduce water with coke, that is, to produce a mixture of hydrogen and carbon monoxide by the action of steam on coke and then to remove the carbon monoxide. This may be done by mixing the gas with steam and passing the mixture through suitable catalyzers, whereby carbon dioxide and hydrogen are formed:

$$CO+H_2O=CO_2+H_2$$

The carbon dioxide can then be absorbed out by scrubbing with water under pressure. This is a promising cheap way of getting hydrogen for use in the synthetic process.

Finally, I would say that the nitrogen problem is by no means a simple one, even at present. In order to supply our armies with the necessary amount of explosives, we shall need to use all our resources: (1) to continue and expand our imports on Chile saltpeter; (2) to introduce as rapidly as possible by-product coke-ovens; and (3) to develop at once new fixation processes. The last is our most vital chemical problem.

I hope that this brief outline may have served to give you a general survey of the situation with reference to our supply of nitrogen compounds and the means available for meeting the demand for them in this country.

[3]The export of nitrates to Germany is now limited to 8,000 tons of calcium nitrate per year, while it is estimated that 112,000 tons (metric) per year will be available for export to the United States and Allies. (Agreement signed April 20th, 1918, by representatives of the Norwegian Government and the War-Trade Board, in effect May 10th, 1918.)

Treatment of War Wounds by Sulphate of Magnesium

DOCTORS MORISON and TULLOCH now obtain very good results in the treatment of wounds by the use of the following solution which is sterilized by heating in a digester of the usual type. Magnesium sulphate, 400 parts, dissolved in a mixture of 100 parts glycerine and 300 parts boiling water. In the treatment of a fresh wound, this is opened widely and a 5 per cent phenol solution is applied for 24 hours, after which the preceding solution is applied by means of compresses. The solution is renewed every 12 hours in the case of suppurated wounds. The pus disappears in two or three days, the scars become detached and the wound is now a bright red color. Growth of the epithelium is rapid, and the treatment can be continued until the wound is entirely healed. The solution should be employed in the above strength, for it is found that weaker solutions are not sufficiently active in the cure. As to the method of action which enters in here, this takes place by osmose, as in the case of Wright's solution. It will be remembered that the latter contains 5 parts citrate of soda and 50 parts salt per 1,000 parts water. Sulphate of magnesia when thus employed, is said to be painless. As it is not absorbed by the system, it cannot exert a harmful action on the white corpuscles contained within the granulations. It has a specific destructive action upon various microbes such as the coli and pyocyanic bacillus.

Wax from Sugar Cane

IN Natal a considerable industry is now being built up by the utilization of the wax, hitherto wasted, which is a by-product of cane-sugar manufacture. The process of extracting the wax was invented by a Dutch chemist, has been carried on in Java, and tried experimentally in Mauritius. The wax, which is equal in value to, and chemically almost identical with, beeswax, is produced from the filter-press cake of the sugar factories. The residue of the filter-press cake, after the wax has been extracted, is used as a fertilizer for the cane-fields, while the wax itself, which has a high melting point and takes a very high polish, is being used by boot manufacturers and furniture manufacturers in South Africa, and also exported for the same purpose to London. As the demand is said to be unlimited, the prospects of the new industry seem particularly bright. There seems no reason why a similar industry should not be started in some of the West Indian sugar colonies.

Indian Medicines*

Numerous Popular Remedies Obtained from Forest Trees

By Hu Maxwell

COMMON tradition attributes to the Indian doctors a wide acquaintance with medicinal plants and a profound knowledge of the curative qualities of herbs. That notion was held by some people who knew the Indians in pioneer times, but usually such persons were not competent judges of a physician's abilities, and an opinion from that source was not worth much. There is no question that some Indian doctors met with considerable success in curing the sick when dealing with simple diseases only; but accounts of Indian doctors curing cancer, tuberculosis, hydrophobia, and cholera, should be accepted with caution. The outstanding fact

Arborvitae

Indians placed leaves and twigs of this cedar in their beds for the purpose of keeping snakes at a distance. Modern campers use it for decorations and like its odor.

of greatest significance was the redman's usual willingness to risk a white physician in preference to one of his own race, when he had the privilege of choosing between them. He had no supreme confidence in the savage doctor with his combination of good medicine and deceptive jugglery; for the two usually went together in the redman's medical practice. For that reason it is difficult for investigators of the present time to arrive at a just estimate of the real merit in the Indian's medicines and methods of applying them. This observation is intended to apply more to the tribes which occupied the eastern part of the United States from one

Yellow poplar fruit

The savages of eastern United States made medicine of bark, buds, and fruit of yellow poplar or tulip tree, and white settlers learned its use from them. It was a fever remedy as well as an external application for sores.

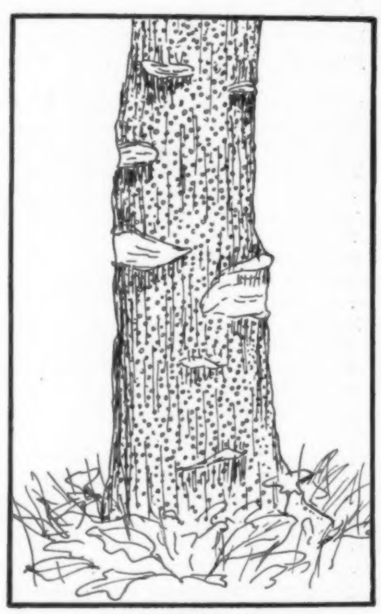
hundred to three hundred years ago than to those which still live in the western part of the country.

Within the past forty or fifty years, studies of Indian medicines have been made by competent scientists who have sojourned among the western tribes, gained their confidence, and learned what medicines the half-savage doctors use and for what purposes and with what effects

Leaf of Beech Tree

Northern Indians made poultices of beech leaves which adhered to the twigs all winter and were easily procurable in time of deep snow. They were a frostbite remedy.

they are employed. The United States Bureau of Ethnology has compiled and published valuable bulletins on Indian medicines of modern times. In these bulletins the botany of plants is correctly given and the methods of preparing medicines are set forth in detail. But information of so accurate and satisfactory a character was very scarce in early years in the eastern part of the United



Umbrella tree

The bitter bark of the *Magnolia tripetela* (umbrella tree) was diligently sought by the red doctors as a cure for chills and fever. It was an article of commerce with them.

States. It is greatly to be regretted that competent scientists did not collect and preserve Indian medical knowledge in early years when there was so much that might have been learned. Intelligent writers on the frontiers were few then, and a great deal of interesting and perhaps valuable information concerning the Indian doctors and their medicines has been lost beyond recovery. The best that can now be done in the way of preserving some of the fragments of Indian medical practice in the forested regions of eastern North America is to search through the books of early travelers, traders, missionaries, hunters, and adventurers. A scrap is to be found here and there which throws a little light on the subject; but such mention nearly always seems to have been accidental. There is no lack of books, and it is remarkable that so much could be written and so little be said on the subject of Indian medicines. Many a frontier writer dwelt at great length upon the practices of Indian conjurers who pretended to cure the sick by beating drums, shaking rattles, and dressing in bear skins and buffalo horns, and dancing before the patient;

Butternut or white walnut

Indians cured many ailments with this tree's bark, and white men learned its use from them. Modern drug stores keep the bark for sale.

but few and short are the actual accounts of the preparation and administering of medicines, though that must have been of common occurrence in the Indian camp and village. It is highly probable that the conjurer and his tricks were called upon in those cases only where the disease was not understood, and that medicines were administered in other cases.

It is pretty certain that the Indian doctors, deficient though they were in scientific knowledge, did not receive justice from the pens of most early writers. In most cases the redman's shortcomings as a doctor are magnified and his virtues belittled, or the subject is entirely ignored. The most notable instance of this is

Angelica tree

Indians called this the toothache tree (*Aralia spinosa*) and made poultices of its bark which served as a counter irritant in toothache. It was a fever medicine also.

found in a series of books known as the "Jesuit Relations," by French missionaries who, during one hundred and fifty years, wrote voluminously of life among the tribes from Nova Scotia to Hudson Bay and New Orleans, and had scarcely a word of commendation for Indian medical knowledge or practice. Those missionaries were

*Courtesy of *American Forestry*.

learned men, and they wrote with the force and fire of the Apostle Paul; but in vain may their seventy-three volumes, which they wrote in French, Italian, and Latin, be searched page by page without so much as one page being found that describes the medicines used by the Indian doctors. The missionaries wrote of things spiritual rather than of those things which appertain to this life and things temporal. This instance is cited merely to emphasize the fact that what is known of Indian medicines has come down from the past as detached fragments.

White ash trunk

From this bark the Indians manufactured one of their thirty-five recorded snakebite cures. Most ash lumber is cut from this species.

Among the scores of men who wrote of Indians and of the frontiers, there were a few who gave more or less information relative to the redman's medicines. One of these was Dr. Benjamin Rush, a signer of the Declaration of Independence, and who was the foremost physician of his time. Dr. Benjamin Smith Barton, of Philadelphia, was another, whose works were published considerably more than a hundred years ago. Peter Smith, a practicing physician on the early Ohio frontier and who said that he "had read some medicine," frankly stated in his book: "I learned some of my remedies from the Indians, or learned them in the same way that the Indians learned them." He called himself "a home old man or Indian doctor." His unique book was long out of print but a new edition was issued a few years ago in Cincinnati. Johann David Schoepf, a Hessian army surgeon who fought against the Americans in the Revolution and afterwards traveled extensively on the western frontiers, left a work in Latin descriptive of American medicinal plants, and another in German descriptive of his travels, and he threw much light on the Indians' practice of medicine. John Lawson's "History of Carolina," written two centuries ago, deals with some of the Indian remedies derived from the forest. Peter Kalm, a Swedish naturalist, writing about 1749 from observations made while traveling through the eastern United States and Canada, gave much interesting information on the same subject. C. F. Volney, a Frenchman who traveled through Indiana and Illinois soon after the close of the Revolution, wrote many careful observations of Indians, including their diseases and cures. Information comes from many other travelers who have left books dealing with phases of Indian life.

Men who were of the medical profession and were personally acquainted with Indian doctors and their medicines have not left wholly favorable accounts of the redman's proficiency as a physician. His knowledge of certain remedies has been admitted, but his skill in administering them has been called in question. That was the view held by Dr. Rush, while the following summary shows Dr. Barton's opinion:

"My inquiries concerning the diseases and remedies of our Indians has convinced me that among these people the art of medicine is truly in a shapeless and embryonic state. It is, nevertheless, certain that some of the rudest tribes are acquainted with the general medicinal properties of many of their vegetables. Medicines of savages are in general medicines of an active kind. The Indians of North America are in possession of a number of active and important remedies. They do not always apply their remedies with judgment and discernment."

Volney reached his conclusions from observations of Indians of the Middle West, and his summary follows:

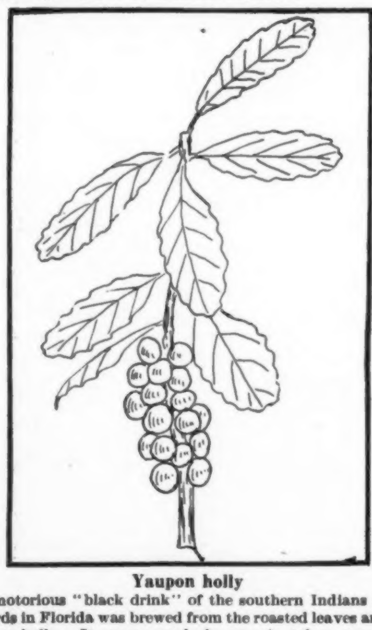
"They are afflicted with diseases of the stomach, intermittent and bilious fevers, consumption, and pleurisy. Fractures and dislocations are not rare among them, but they are pretty dextrous in reducing them. They would suffer more from rheumatism if they did not practice fumigation by means of hot stones."

Common elder

The bark was beaten to a pulp by Indian doctors and was applied as a poultice to relieve toothache. It was afterward used extensively by civilized physicians. The bark contains hydrocyanic acid and is poisonous.

Shellbark hickory

Oil made from hickory nuts was used as liniment by Indians to "supple their joints." May apples, also used as medicine by the savages, are seen growing near the base of the tree. This is the *Podophyllum pelatum* of the modern drug store.



Yaupon holly

The notorious "black drink" of the southern Indians and the Spaniards in Florida was brewed from the roasted leaves and twigs of yaupon holly. It was a remedy for anemia, taken once a year.

Schoepf's opinion of Indian medicine and practice was given in these words:

"Most of the diseases for the healing of which the skill of the Indians is specially praised, are simple, those in which nature may work actively and effect most salutary changes. The observers and panegyrists of the so much belauded Indian methods of therepy are commonly ignorant people who find things and circumstances wonderful because they cannot offer explanations from general principles. The medicines of which they make use are few and simple, potent naturally or through the heaviness of the dose.

Wild cherry

This tree's bark furnished tonic to northern Indians and was likewise employed in fevers. It is still considered valuable as a medicine.

Indian doctors seldom compounded medicines. Each was complete in itself. If they used cherry bark, they mixed nothing with it; if dogwood flowers, they were used alone; if beech leaves, they alone were employed. The old medical books called such remedies "simples," because only one ingredient was present.

After the Indian came in contact with white men he speedily acquired most of the diseases of civilization, but while he lived in his natural environment his ailments were fewer in number. Judging from statements in old books dealing with the matter, Indians suffered chiefly from four classes of complaints, but the classification here given is not scientific.

The first may be defined as aches for which the Indian could discover no visible cause, such as rheumatism, toothache, and headache. There is no question that the savages suffered severely from these.

Fevers constituted the second class, and all accounts agree that Indians suffered from that cause. It may not be possible to diagnose the cases sufficiently to determine at this late date what kinds of fevers prevailed, but the old-fashioned "fever and ague" was common. It could not have been otherwise, for mosquitoes were swarming in the woods, and among them doubtless were numerous anopheles, the species which transmits the germs which cause ague. Naturally Indians would suffer greatly from the bites of these germ-carrying insects, and chills and fever would develop. Contemporary writers bear abundant testimony that malarial sickness was common among the Indians, and the red doctor knew what medicines the forest afforded for the cure of intermittent fevers.

Wounds constituted the third class of sickness calling for cures. The most usual wounds were cuts, bruises, sprains, fractures, burns, and frostbite. The savage's mode of life made these hurts of frequent occurrence.

The fourth class might be listed as a subclass of the third, but it was so common and so distinct that it properly stands separate from others. It was the wound caused by the bite of a posionous snake. Every part of the United States was infested by venomous serpents, and the bare-legged savages, walking through weeds and among rocks, were peculiarly liable to attack. The Indian doctors ransacked the American forests for snake-bite remedies, and no fewer than 35 separate cures, or alleged cures, were known and used, but not all in the same regions. All of these were derived from trees and herbs. Several plants known as "snake root"

have come down to the present day. Two of the best known are "Virginia snake root" (*Aristolochia serpentaria*) and "Seneca snake root" (*Polygalia senega*). The Virginia snake root was so highly valued by the Cherokee Indians that they placed an embargo on its export, with the death penalty for any one attempting to carry the forbidden root out of the country.

Quinine was unknown to the Indians who inhabited this country in early times, but they sought out the best obtainable substitutes for it and used them as medicines in treatment of fevers. Several native trees yielded bark, flowers, or fruit so bitter in taste that they filled the place of quinine. Some of those remedies were adopted by civilized physicians as treatment for intermittent fevers.

One of the most widely used fever medicines employed by the Indians was dogwood (*Cornus florida*). The tree grew in nearly all forested regions east of the Rocky Mountains, and other species very similar were found in some parts of the United States, so that Indians in widely separated regions could procure it. Flowers, fruit, and bark were steeped in water and were thus made into an intensely bitter drink which was administered in large doses. White physicians who learned the rememdy from the savages used whiskey or gin as the fluid part of the medicine, and it has remained in use to the present day, though it is not so popular as it once was. It was the "bitters" formerly prescribed by many a country doctor for "fever and ague," just as the Indians administered it.

Yellow poplar (*Liriodendron tulipifera*) was as bitter as dogwood and Indians administered it for the same purpose. They preferred bark to the roots, but the inner bark of the trunk and even the green fruit, were given as a chill and fever remedy. The white man adopted that remedy from the Indians and occasionally he still employs it.

The angelica tree (*Aralia spinosa*) supplied a fever medicine which enriched the savage doctor's pharmacopoeia. The inner bark was used. It is less bitter than dogwood and yellow poplar, but it possesses a peculiar acrid taste which commended it to the barbarians; for the more disagreeable the taste, the greater virtue in the medicine, according to their opinion.

Greasewood (*Covilea tridentata*) was a medicine formerly in use among the Indians of the southwestern arid region of the United States. The leaves and twigs were boiled and the resulting tea was drunk. It is not very bitter and its efficiency as a fever medicine is doubtful. It is not a tree but a shrub. It is the purpose to restrict this article pretty closely to medicines derived from trees; but it may be allowable to include this species of greasewood. It is one of a group of related species of which some of the western Indians made arrows, and in so doing they had their mouths constantly filled with the bark, because it was their custom to strip off the bark with their teeth from the young shoots in the process of arrow making. Small crooks in the stems were straightened by using the teeth as a vise. The arrow maker pronounced the bark "good medicine for the stomach," and that may have led to the use of greasewood tea as a medicine by those who felt the need of it. The Pima Indians were still using this remedy a few years ago.

Indians had as much toothache and rheumatism as the less barbarous people, and they suffered from headache, and had remedies for these and kindred pains. They were able to extract their own teeth by attaching a sinew or cord to the aching member, tying the other end to the limb of a tree, and allowing their weight to give the necessary pull. But they had cures without surgery.

Writing about the year 1794 Loskiel, a German traveler, said in his "History of the Missions of the United Brethren Among the Indians of North America" that the Indians applied the bark of the "toothache tree." or prickly ash, as a cure. That tree was the same as the angelica tree referred to above as a fever cure. It was also known as Hercules club, which name it still bears in some regions. There are two species known as toothache tree and Hercules club in this country, both of which were used as medicine by the Indians. The northern species to which Loskiel referred was *Aralia spinosa*. The southern species which is known by the same English and Indian names, is designated by botanists as *Xanthoxylum clava-hercules* and is wholly different from the northern tree which it so closely resembles.

Butternut (*Juglans cinera*) was another toothache remedy among the Indians, and was likewise employed to relieve headache and rheumatism. Loskiel refers to it in his book as follows, speaking of the savages which at that time inhabited Ohio and Pennsylvania:

"For rheumatism some apply the bark of the white walnut to the part affected, by which the pain is frequently removed and an eruption produced in some parts of the body. It is extremely acrid and occasions a pungent pain on the part of the skin to which it is applied, which afterwards appears as if it had been scorched. For the headache they apply a small piece of the bark to the temples, and for the toothache on the cheek near the tooth affected."

Butternut bark, and also the bark of the angelica tree, have been in use as medicine by regular physicians ever since the secret was learned from the Indian doctors, but no longer as toothache remedies.

The common elder (*Sambucus canadensis*) is still another addition to American medicine learned from the Indians. Peter Kalm said in 1749 of this elder as a toothache cure:

"I have seen the Iroquois boil the inner bark and put in on that part of the cheek in which the pain was most violent. This, I am told, often diminish the pain."

Early American doctors laid great stress on the elder as a source of medicine, and they used every part of it, flower, fruit, bark, root, and pith. Some parts of it are still for sale in drugstores, but elder does not enjoy the reputation it once had. Fortunately the Indians who suffered from toothache applied the elder bark to the outside of the cheek instead of the inside of the mouth, for elder bark is a deadly poison, due to the hydrocyanic acid it contains, and it has been known to cause death almost instantly when swallowed. Who knows how many Indians were fatally poisoned before they learned to apply the elder toothache remedy externally instead of internally? The Indian's usual treatment for rheumatism was a steam bath in an airtight hut; but he had remedies of other kinds, chiefly drinks made from bark and roots. One of the Indians' favorite cures for rheumatism and valued higher than probably any other tree, so far as it was known, was the umbrella tree (*Magnolia tripetela*). This is known also as cucumber tree, magnolia, and elkwood. It is found among the Appalachian Mountains of Pennsylvania and southward, and in some localities as far west as the Mississippi River. The grouping of the leaves on the outer ends of the branches, in the form of a parasol, gives the name "umbrella tree." In Dr. Barton's "Collections," published in 1798, he speaks thus of the umbrella tree:

"The bark of this tree is celebrated among the western Indians as a remedy in rheumatism and fevers. The tree grows in great profusion upon the River Kanhaway (Kanawha) whither the Indians resort for the purpose of procuring the bark which they carry off in great abundance. It is known as elkbark and Indian bark."

Barton must have had in mind a period much earlier than his book, 1798. The Kanawha River is in West Virginia, and the Indians were driven from that region by Gen. Andrew Lewis in 1774, and they never returned. The bark-gathering expeditions spoken of must have belonged to a much earlier date. It is worthy of note, too, as a record of forest change, that though the umbrella tree may once have existed "in great profusion" in that region, it is difficult to find a single tree of that species in all that country at the present time. The report on the trees of West Virginia, prepared by A. B. Brooks for the state geological survey, makes no mention of this species, and it is presumed that it was not met with in the region where it was formerly abundant.

The Indians made an oil from hickory nuts and black walnuts and used it as a liniment "to supple their joints," according to the testimony of an old writer. That remedy was employed frequently by Indian fishermen who waded much in the water along the tidal rivers of Virginia and Maryland where half the savage population lived by fishing. Rheumatism and stiffening of the joints, due to exposure, were common complaints, and the frequent application of nut oil gave relief. It seems probable from early accounts that hickory trees were more plentiful than any other forest tree species in the Virginia coastal region at that time, which was the period of first exploration by white men. At that time the loblolly pine (*Pinus taeda*) was confined chiefly to tracts near the mouths of rivers and had not yet spread inland as it has since done, and hickory held chief place in the forest's makeup in that part of the country.

Most of the cures for snakebites, which the Indians made use of, were annual plants and therefore do not fall within the scope of this article which deals with trees only; but the white ash (*Fraxinus americana*) was employed as a remedy, according to Loskiel, who says in speaking of the bite of snakes: "A decoction of the buds or bark of white ash, taken inwardly, is said to be a certain remedy against the effect of this poison."

Indians of the Lake States and of parts of Canada placed much reliance on arborvitae (*Thuja occidentalis*) as a protection against snakes, though it does not appear that they actually applied it as a medicine. They went on the theory that an ounce of prevention is better than a pound of cure. It is written in volume 3 of the "Jesuit Relations":

"In the forests (of the Huron country) are seen abundance of cedars. The odor of the tree is disliked by serpents, and on this account its branches are used for their beds when on their journeys."

Arborvitae possesses a camphor-like odor which is very perceptible when the leaves and twigs are bruised. The present day camper in the country north of the Great Lakes is glad to furnish his camp bed with arborvitae boughs, which he calls "spruce feathers." The odor might have kept snakes out of his wigwams of the Huron Indians two hundred years ago in the palmy days of the Jesuit missionaries; but at the present day the camper regards the delicate odor as one of the luxuries of forest life, and it is that which now gives the boughs their value, and no one regards them as protection against serpents. In fact, it is doubtful if snakes shun this tree, for they hide in arborvitae hedges as readily as in any other hedge.

Indians had no infallible snakebite cure. An early traveler in Florida asked whether an Indian when struck by the large, black rattlesakes of that region ever succumbed, and he received the answer: "I never knew of one so bitten that did not succumb." The blunt, thick rattlesnake of Arizona, known locally as the "sidewinder," is reputed to cause sure death when it strikes an Indian; but that point does not seem to have been investigated scientifically. So far as the writer of this has been able to ascertain from reports of the Bureau of Ethnology, the only case reported of an Indian bitten by a rattlesnake in Arizona was one that proved fatal, but it was assumed in that instance that death resulted because the victim was unable to apply a remedy promptly. Indians of Arizona and surrounding regions made themselves leggings of hard leather as protection not only against snakes, but also against the fierce thorns which bristle on every leaf and stem of the desert vegetation. Prevention was easier and safer than cure. To this day if an Indian of certain California tribes is bitten by a rattlesnake and cannot get aid from white people, he gives up to die, believing that there is no hope. Such a bite is not, however, necessarily fatal.

Cuts, bruises, sprains, frostbites, and many other injuries of a like nature, were common among the Indians; and the trees of the forest furnished poultices, salves, and liniments in profusion. The bark of slippery elm (*Ulmus pubescens*) was as great a favorite among the savages as it was later and still is, with the civilized physician. All drug stores sell it; but long before there were drug stores in America, the red doctors understood the healing properties of this bark. John Lawson, who has been already quoted, wrote of this remedy as follows more than two hundred years ago:

"The Indians take the bark of its roots and beat it whilst green to a pulp and then dry it in the chimney where it becomes of a reddish color. This they use as a sovereign remedy to heal a cut or a green wound."

One hundred and forty years after Lawson's time, one of the foremost physicians of America, Dr. Wooster Beach, paid the following high compliment to elm bark, the use of which had been learned from Indian doctors:

"It quickly and powerfully allays inflammation, promotes resolution, also suppuration, and heals speedily. We make extensive use of the flour of the bark in the form of poultice, for every variety of inflammation, wounds, and ulcers. In point of utility, it is of far more value than its weight in gold; and, therefore, whoever has a tree on his farm should never permit it to be cut."

Slippery elm is easily distinguished from the four other elms of this country by its thick mucilaginous inner bark, but its leaf assists frequently in identifying it. Its apex is usually longer and narrower than the apexes of the leaves of other elms, and the leaf feels rough and harsh, no matter in what direction it is rubbed. When the leaves are crushed in the hand they give a crackling sensation.

The fruit of yellow poplar, beaten, boiled, and made into salve, was an Indian remedy of which an early traveler wrote: "The buds, made into ointment, cure scalds, inflammations, and burns. I saw several bushels thereof."

Indian doctors were able to do more with the leaves of the common beech tree (*Fagus atropunicea*) than modern doctors are doing, for current dispensatories do not mention beech leaves. John Carver, who traveled on the headwaters of the Mississippi River at a time when the region was practically unknown to white men, thus wrote of the medicinal value of beech leaves in winter:

"The leaves which are white, continue on the tree during the whole winter. A decoction made of them is a certain and expeditious cure for wounds which arise from burning or scalding, as well as a restoration for those members that are nipped by frost."

Beech is one of the few deciduous trees whose leaves remain on the twigs during the winter and they are thus preserved against decay. That fact probably suggested their use to the Indians.

The bark of white pine (*Pinus strobus*) was made

into poultices for burns and other sores; and this remedy has come down to the present time, and this pine bark is still in the market. It runs high in tannin and resin.

The Indians administered tea made from the bark of sassafras roots, also from buds and flowers, as an internal remedy for wounds. The tea is in wide use yet, as a popular blood purifier, and is drunk in early spring by many a person who does not know that it is an Indian medicine handed down from past centuries.

Mesquite (*Prosopis juliflora*) supplied the great eye lotion for the Indians of the Southwest. The glare of the sun in that hot, arid region, is severe on the eyes and is apt to produce chronic inflammation of the lids. The Indians concocted an eye wash from the mascerated leaves of mesquite by squeezing the juice through a cloth to rid it of solid particles. The eyelids were bathed in the liquid. The savages made use of the white inner bark of mesquite, beaten into powder and boiled, in preparing a medicine which they administered internally for a number of real or imaginary diseases.

The wild Indians had no such classic name as "anemia" for that "run-down feeling" which comes in the spring and early summer; but they had the malady and they had the remedies. In the North they drank tea made from wild cherry bark, and in the southern coastal region of the United States they imbibed enormous quantities of their famous "black drink" which they brewed from the leaves of yaupon holly (*Ilex vomitoria*). They journeyed from far inland to the Carolina coast to procure it. The roasted leaves, made ready for brewing, were an article of commerce between the coast Indians and those of the interior. One of the earliest and best descriptions of the brewing of the drink was published in 1716 by John Lawson. It follows:

"Cattle and sheep delight in the plant very much, and so do the deer, all which crop it very short, and browse thereon whensoever they meet with it. This plant is the Indian rea, used and approved by all the savages on the coast of Carolina, and from them sent to the westward Indians and sold at a considerable price; all which cure after the same way as they do for themselves, which is thus: They take the plant (not only the leaves but the smaller twigs along with them) and bruise it in a mortar until it becomes blackish, the leaf being wholly defaced. Then they take it out and put it in one of their earthen pots, which is over the fire, until it smokes stirring it all the time until it is cured. Others take it after it is bruised and put it in a bowl, into which they put live coals and cover them with yaupon till they have done smoking, after turning them over. After all, they spread it upon their mats and dry it in the sun and keep it for use. The Spaniards have the plant very plentiful on the coast of Florida and hold it in great esteem. Sometimes they cure it as the Indians do, or else beat it to a powder, so mix it as coffee; yet before they drink it they filter the same."

The yaupon drink was a violent emetic, and the Indians used to imbibe so long and in such amounts that they were scarcely able to walk, continuing the process during several days. They then departed for their homes, feeling certain that they had been fortified against disease for another year.

The British Canal System*

THE announcement that the Government have taken steps to assume control for the period of the war of the independently owned waterways is the natural sequence to the control which has been exercised, through the Railway Executive, of the railway owned canals since the outbreak of war, and it places for the first time all methods of transport by shipping, rail, and road, under national direction. It is known that, in consequence of the congestion on the railways, a greater use has been made than in normal times of the waterways under railway direction, and whatever may be the economic reasons which have gradually diverted traffic from waterways to rail and road, it is probable that under present conditions the intervention of the Government will enable the companies also to work the canals they own on a more effective basis.

A CHAPTER OF HISTORY

British inland waterways, unlike those of France, Belgium and Germany, have been almost entirely the result of private enterprise, and form a worthy memorial of the activities of the early generation of engineers. The system which is quite extensively developed had its beginnings with the construction of the first Bridgewater Canal, for the transport of coal, from Worsley to Manchester in 1761, and the financial success of the early undertakings which encouraged the provision of capital, reinforced, as it was, by a high order of engineering ability, led to the construction of canals over large areas of difficult country, involving in many instances the provision of costly flights of locks, aqueducts, and tunnels, as well as the construction of reservoirs at high altitudes to maintain the necessary supplies of water for the upper reaches of the canals. The existing system in the United Kingdom, including canalized rivers, extends to about 4,670 miles, nearly a third being railway-controlled, and was, except for the Manchester Ship Canal, completed before 1830, the year in which the Liverpool and Manchester Railway was opened for traffic. The prosperity of the canals, which at one period maintained regular passenger as well as goods services, diminished as the railway era advanced, and although on certain favored sections, under the stimulus of capable management, traffics have been maintained and even increased, the waterways, as a whole, have had little share in the enormous development of internal transport which has characterized the last 50 years. On the Continent, however, large sums have been expended during the modern era in the improvement and extension of waterways, and the majority report of the Royal Commission on Canals in 1909 expressed the belief that this has resulted in "great cheapening of the expenses of transport of certain classes of goods and a consequent extension of trade."

*Engineering Supplement of the *London Times*.

RIVER NAVIGATIONS

Before dealing with canals proper a brief account may be given of the rivers which are connected with the artificial waterways and form the final link in the chain connecting inland districts with the sea. These are the Thames, Severn, Trent, Yorkshire, Ouse, Humber, Bedford Ouse, and the Nene. On the Thames there is a considerable traffic between Staines and the sea, the locks below this point being of large size. There is, however, much room for improvement in the upper reaches, particularly above Reading. The Severn is navigable up to Worcester for vessels carrying 200 tons and barges of 100 tons capacity can reach Stourport. Above that town, owing to neglect, navigation in the commercial sense has entirely ceased. The Trent navigation, on which somewhat important improvements are projected, is handicapped by the want of sufficient water in dry seasons and by floods in wet ones, but is used for through traffic up to the junction with the Trent and Mersey Canal at Derwent Mouth. The Yorkshire Ouse is mainly used up to York by vessels of about 90 tons, but steamers up to 225 tons can traverse the waterway. York is well situated for becoming an important inland port, in direct communication with the Aire and Calder and other navigations, as well as with the East Coast ports. In the case of the Humber the condition of the river above Hull has been the subject of an improvement scheme which should be of considerable benefit to the navigations connected with the Ouse, the Trent, and the Aire and Calder, as well as to the port of Goole. The Bedford Ouse and the Nene, the two most important rivers in the Eastern Counties, have been subjected to a policy of neglect which has practically destroyed traffic on the Ouse, while the Nene, which is the link between the London and Midland and the Eastern Counties waterways, is now useless as a means of through communication.

CANAL CAPACITIES

A large mileage of English and Welsh canals form part of a connected system. Over this system cargo boats of the narrowest type—that is to say, boats 70 feet to 72 feet long by 7 feet wide—can pass from one point to any other point. These connected water-ways lie chiefly in the Midlands and the southern part of the Northern Counties, and there is no connection by inland water routes with Scottish rivers and waterways or with the Welsh canals.

A broad classification divides the English and Welsh systems into five main groups. These are the Midland group, consisting of canals which radiate from Birmingham to the estuaries of the Thames, Mersey, Severn, and Humber; the Southern group, consisting of the River Thames and the navigations connected with it; the waterways of Lancashire and Yorkshire, which have been carried over the hills and moors, and give communication between the west and east coasts; the East Anglian group, and the canals in Wales.

The traffic capacity of these waterways is governed by the dimensions of locks, depth of channels, and headway of bridges and tunnels. A study of the lock question indicates that a crude division may be made into the two classes—those waterways having locks over 14 feet in width, and those having locks of a smaller width. The usual length of both the narrow and wide locks is 75 feet, and the available statistics show that about 1,165 miles of canals are narrow lock waterways, and that 762 miles have been equipped with locks of more than 14 feet in width.

These figures reveal the restrictions which the break of gauge caused by locks alone imposes on through carrying capacity, and explain why hardly any of the inland waterways are efficient on a competitive basis with other forms of transport in the light of present-day needs. The deficiencies of the system could be illustrated in detail, but a few dominant facts will show what they are. There is but one canal of importance now linking the Thames and Severn estuaries—the Kennet and Avon, and only a narrow boat with an extreme limit of 30 tons, capacity can be loaded in London for the Birmingham area. The great Birmingham canal system, owned by the London and North-Western Railway, consisting of 159 miles of waterways, is narrow throughout, extremely complicated in character, and has no locks except on the small scale. There are several long tunnels, one of nearly 4,000 yards, and owing to the altitude of the canals there are difficulties in connection with water supply. Narrow boats alone can pass from the Birmingham district to the estuaries of the Mersey, the Severn, or the Humber. In spite of these handicaps a large traffic is handled by the Birmingham canals.

Even a well-maintained canal like the Trent and Mersey, the main route from east to west, has its usefulness restricted by its limited section. The story could be easily extended. Sometimes the difficulty arises from want of required depth of water or long chains of locks with their attendant loss of time, or the diameter of tunnels, or the height of overbridges. The result is the same; the requirements of modern traders can be met only to a very limited extent, and declining revenues have in the case of too many of the independently owned waterways left no surplus for improvement or even adequate maintenance.

AIRE AND CALDER AND WEAVER SYSTEMS

The notable exceptions to the general disadvantage under which canals labor are the Aire and Calder and Weaver navigations. Adding to the natural advantage of the fairly easy country traversed the benefits of good equipment and management, the Aire and Calder navigation, which serves Goole and the Humber, has succeeded in attracting a large and regular coal traffic. Capacious locks, an adequate supply of water, and the introduction of a special system of compartment boats for coal transport have enabled the waterway authority to compete effectively with railways serving the same territory. In its physical characteristics the Aire and Calder approximates in character rather to Continental than British waterways.

The Weaver navigation, with locks capable of receiving four 250-ton vessels at one time, and its lift at Anderton giving connection with the Trent and Mersey Canal—thus avoiding the interminable delays of a chain of locks—is also a fine example of waterway enterprise, and carries a large salt traffic from Cheshire to the Mersey.

COMPARISON WITH CONTINENTAL WATERWAYS

Reference is often made by the advocates of State aid for waterways development to the conditions which obtain on the Continent, where, under Government auspices, large sums have been expended on schemes of improvement and extension. It is necessary that the difference in the physical and traffic conditions should be realized before jumping at conclusions on this subject. There are many points in this connection which merit consideration. It is certainly the case that in North Germany and Northwest Belgium the engineering conditions are much more favorable to canal construction and the water supply more abundant. The country is level and very long lengths of canal can be constructed without locks, although it should be noted that where physical and engineering difficulties of no mean order have to be surmounted, as in the Rhine-Danube Canal or the Brussels-Charleroi Canal, or that connecting the Marne with the Rhine, these have not deterred Continental Governments and canal engineers from embarking on the work. These conditions, however, are on the whole exceptions; in this country they are the rule.

Water supply is another problem which has presented greater difficulties in Great Britain than on the Continent. Artificial reservoirs for augmenting the supply to the waterways are very rare in Germany and Belgium, and even in France the mileage of waterways dependent on reservoirs for maintaining the required depth for navigation is much smaller than in England and Wales. More progress has been made on the Continent in traction developments than in England, and it would seem that mechanical towage is destined to supplant horse traction entirely. Electric haulage systems are making considerable headway, particularly in France. In England, with the exception of steam towage and experimental working with barges fitted with internal combustion engines, but little has been done. The physical conditions of the waterways form the limiting factor in the application of new traction systems on British canals, and it is not likely that Government control will lead to any immediate or extensive developments of a mechanical character. But it should be possible to obtain better utilization of existing facilities and to relieve the companies of certain difficulties in respect of labor.

Scene inside the hull of a wooden ship under construction. Putting in floor ceiling

Fitting the bilge clamps, and securing them by long iron bars riveted at each end

Familiar Scenes in a Modern Shipyard

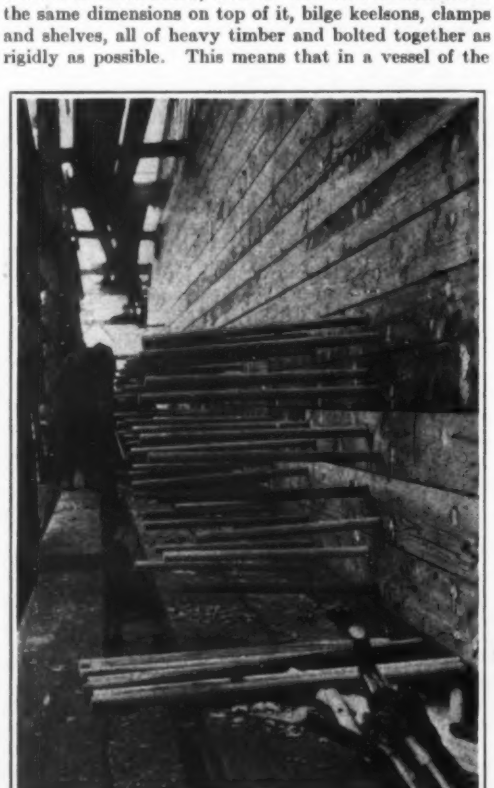
Some Facts on Wooden Construction

THE old wooden ship has unexpectedly come back into service, as a result of transportation conditions rather than on its merits; the general public however, having little knowledge of the merits of the case, have accepted the proposal to build a large number of these antiquated vessels with a kindly favor that probably results from the human interest that clings to the wooden ship. In their every line they suggest the handiwork of man, as compared with the machine-like construction of the steel ship; and, moreover, everyone is susceptible to the picturesque effect of a noble vessel under full sail, with her white canvas gracefully rounded by the breeze; so we have with easy good nature accepted schemes that will probably prove of more permanent value to the contractors and the lumbermen than to anyone else.

At its best a wooden ship is a curious and ingenious patchwork that still retains many fundamental features found in the earliest craft of which we have any records, and which modern ingenuity has found no way to improve. But there is one characteristic of a wooden ship, and which also is inherent in the concrete ship, which many, with but a superficial knowledge of the subject, fail to realize; and that is that it is not possible to increase strength and stiffness in proportion to increase in size. This makes the construction of a ship to be of material value under present conditions a matter of hazard, even with experienced builders; and there is every reason to believe that this has proven to be the case in more than one instance. It will be noticed that practically no reports of progress in wooden shipbuilding are being published.

At the top of this page are views taken in the interior of a wooden ship, and it will be seen that the frames, or ribs, are built up of a large number of short pieces of timber, laid up in two widths, side by side with joints alternating. The two members of this double frame are joined together as strongly as possible by numerous side bolts; but at best it cannot be considered a rigid structure, especially in the larger sizes. In the old days these frames were set up, piecemeal, in place, but now they are "fabricated" on the ground much quicker, and swung into place by a derrick, as shown on the next page. In former times each of these numerous carefully curved bits of timber were slowly hewn out by hand, and it took many months to frame up a vessel of moderate dimensions. Now machinery has been adapted to this special work, and it is possible to produce rapidly the most complicated shapes in a surprisingly short time. Even the "cant timbers," as the frames at either end of a ship are called, and which frequently call for compound curves, and a rhomboid section, can be cut with speed and accuracy.

It is not generally appreciated that the interior of a wooden ship is planked up, the same as the outside, but such is the case. Moreover, this interior planking, or "ceiling," is usually much heavier than the outer planking, and in a 280 foot ship the specifications call for floor ceiling 8 inches thick; bilge ceiling 12 and 15 inches thick and side ceiling 10 inches; while the outside planking is 5 and 6 inches. All of this is required in an endeavor to get longitudinal stiffness; and in addition there is the keel 20x20, with several tiers of keelsons of the same dimensions on top of it, bilge keelsons, clamps and shelves, all of heavy timber and bolted together as rigidly as possible. This means that in a vessel of the above size the sides would be about 30 inches thick of solid wood.

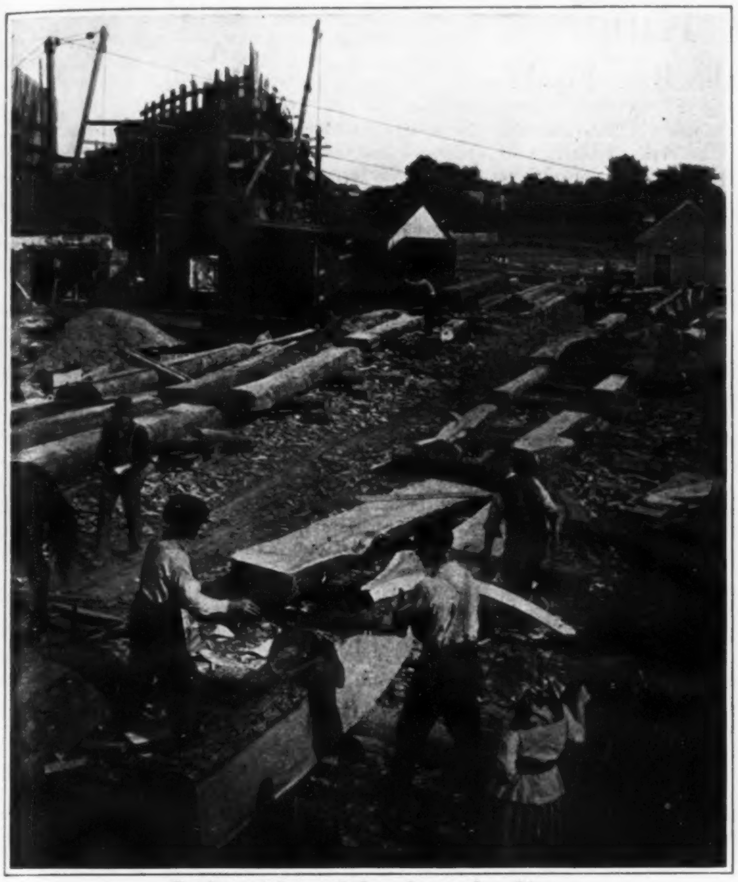


Locust wood "treenails" bind the heavy planking to the interior framework

The fastenings used in the construction of wooden ships are of varied character. The heavier parts of the framing, such as keel and keelsons, deadwoods, etc., are bolted together by heavy rods of iron, tightly driven, and headed at each end over washers. The outside planking is first spiked in place, and then secured at every frame by a "treenail," made of black locust wood, which is remarkably tough and durable. A hole is bored through the planking, rib and ceiling, and the treenail driven through to the inside of the structure. The ends are then cut off flush with the surface of the planking, and each end is then split with a chisel, and a white pine wedge is driven into the cleft to spread the ends of the treenail, to prevent it from pulling out. Wooden pegs of this kind are relics of the earliest known methods of shipbuilding, but for this particular purpose nothing better has ever been discovered, for, when a wooden ship is in a seaway, there is more or less unavoidable movement between the various parts of its structure, and these tough locust wood treenails, while yielding somewhat to this movement, still retain a most tenacious grip and maintain the parts in their relative positions without loosening. One of the accompanying illustrations shows the side of a ship with a number of treenails set in holes, ready for driving; and the finished ends of a number of others can be distinguished.

Sparmaking is another part of the shipbuilding trade where machinery has materially lessened the amount of hand labor required, for, whereas, in former times masts, yards and booms were slowly shaped by hewing, shaving and planing, now, on the Pacific coast, where wooden shipbuilding has been carried on continuously on quite a large scale, machinery has been developed for manufacturing these heavy spars from the famous Oregon pine, which is the best spar material in the world.

Big spars for wooden ships



Getting out frame timbers for wooden ships

Steaming a timber preparatory to bending it into place

One of the illustrations shows the caulkers at work, a familiar scene in every shipyard; but quite recently a machine has been developed for doing this work much faster than it can be done by hand, and soon the peculiar ringing stroke of the caulking mallet will cease to be heard, even if wooden ships continue to be built after the war.

Up to about 180 to 200 feet length very satisfactory ships can be built of wood, but to attempt vessels of 300 feet, or more would seem extremely hazardous in view of past experience of competent builders. It is very easy for a theoretical engineer to argue that a ship is simply a phase of bridge construction, and to demonstrate his proposition on paper, but in a ship at sea we have the bridge irregularly loaded, and supported by a most complicated system of forces that is constantly varying in quantity and direction—moreover, it is not necessary to make the "bridge" watertight. Theory and practice in this case do not agree.

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Erecting the fabricated frame of a wooden ship

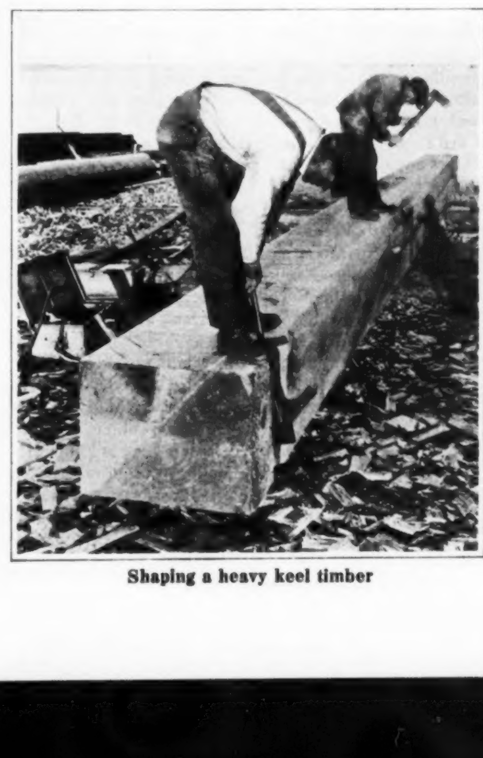
Emulsions

The use of gasoline and similar organic solvents for japan is attended by a considerable fire and accident risk, and hence it seemed desirable to devise some means of applying japan which did not involve the use of inflammable solvents. It has been found possible to emulsify the oils used in making japan bases (linseed oil, wood oil, etc., their compounds and polymers) by merely heating them with an aqueous solution of an alkali in an enclosed space. The alkali used in the present experiments was ammonia. Since the emulsification can only take place at the interface between the oil and the water, the process may be hastened by means of a stirrer with baffles, rotating at 30 to 60 r. p. m. All the alkali and a little water may be added to the oil-phase (in this work the japan base) at first, later adding water gradually, or the whole of the water may be added to the alkali and oil-phase at once. At present, the first method is to be preferred, since it gives an emulsion the appearance of greater fineness.

All emulsions thus made have formed a scum on the surface if left exposed to the air at room temperature. This has been shown to be due to CO_2, for if air from the room is carefully freed from CO_2, it may be bubbled through the emulsion for a whole day without the formation of scum. If, however, the temperature of the emulsion is kept below 16° C., no scum will form in the presence of CO_2-laden air. The droplets of the discontinuous phase of the emulsion are negatively charged. This offers a method for separating the discontinuous from the continuous phase by the introduction of electrodes into the emulsions. The deposition of the discontinuous phase upon the anode is an example of real electroplating, for the amount deposited is strictly proportional to the product of the current and time, and is independent of the voltage employed except in so far as the voltage affects the strength of the current. No attempt has been made to measure accurately the velocity of transport of the discontinuous phase under an electric field, but rough measurements indicate that it is not less than 10^{-4} cm. per sec. per volt-cm. This is of the same order as the velocities of other colloids and ions at the same temperature.—Note in Sci. Abs. on a paper by W. P. Devey in *Phys. Rev.*

New Method of Extracting Foreign Bodies, Using a Radioscopic Screen

This method appeals by its simplicity. No special apparatus is required beyond the bulb, screen, and a pair of pincers. The point of incision being chosen, the tip of the pincers is placed in the incision made in the skin and the screen is put in position. The object then is so to arrange the pincers that the prolongation of its shadow on the screen shall cut that of the projectile for two different positions of the bulb. When this has been done the direction of the pincers gives the line of incision leading to the foreign body. The method of procedure when the shadow does not fall in the correct line is dealt with in detail.—Note in *Sci. Absts.* on an article in *Comptes Rendus.*



Shaping a heavy keel timber

Corn Is King*

Will It Become the Base Food?

At least 95 per cent of the world's wheat crop is eaten by human beings; not 8 per cent of its corn crop is so eaten. The production of corn exceeds the production of wheat, and it is grown over a much more extended area. Very little corn is transported away from where it is grown; two-thirds is consumed on the farms where produced, and much of the other third within the limit of horse-drawn or motor carraige. Wheat and wheat flour are subjects of long hauls by rail or vessel. Wheat in the form of bread is the most acceptable of all human foods; wherever available it displaces all other grains, roots, and tubers. Corn is eaten only when wheat is not available; for the rest it is stock feed. Corn is America's greatest gift to the world; its value is appreciated, but not to the full extent; this will come when we know how to prepare it as human food. Some such marvel as Charles Lamb fancied to have been wrought in pigs by the roasting must also be wrought in corn.

In the August (1917) number of the *Bulletin* of the Pan-American Union under the title, "Wanted, a New Bread," an attempt was made to state in more or less exact terms the problem of basic food which now confronts the world, and which beyond any doubt will, if unsolved, press even harder after the war than it does now. The purpose of the writer was to lead investigators away from the inconsequential, although not necessarily from the temporary. The subject of food is being studied now as it never was before. The need for this study is apparent to everyone and it should receive every encouragement. There will be unproductive effort; there must be, but this is not necessarily wasted effort. It is only wasted when directed toward a problem itself not understood. The writer believes that a clear comprehension on the part of the thousands of investigators, many of them very competent, of just what is the problem they have on hand will lead to its solution in a short time. He himself has no solution to offer. His fitness, if any, is in assembling the material facts, the known quantities, and in pointing out the starting point for the investigation.

No one will contend that bread is indispensable. Man can live without bread; as a matter of fact, the greater part of mankind does; yet, notwithstanding, bread is the basic food of all higher civilizations. The food economics, and to a large extent the agricultural development of Europe, America, and wherever else the white race dwells, is based on bread. Black, brown, and yellow people follow in the footsteps of the white and become bread eaters. Bread will, if available, conquer the whole world. It does not necessarily displace other foods, but it renders all such secondary. Its march has been irresistible.

The bread here spoken of is wheat bread; rye to be considered as a sort of wheat although less adaptable to bread making. Satisfactory bread can not be made of other grains—rice, potatoes, or like starchy foods. In fact, notwithstanding barley bannocks and corn pone, true bread without wheat flour is not yet possible. Some of the confections of buckwheat, barley, corn meal, and oatmeal, particularly when served hot or made with eggs, milk, and butter, are tasty cakes, but they are not bread. Formerly what might, by some stretch be called bread, was made of corn and eaten in the United States, especially in the Southern States, and it is yet eaten in Mexico and other parts of Latin America. This was of plain corn meal with a little salt and water. This kind of bread disappears everywhere when wheat flour bread is available. Even the southern colored farm laborer has almost entirely ceased to eat corn bread except when eggs and milk for the making are to be had. But why? Corn in any other form than bread is as tasty as wheat. It has equal food value. It has a broader food use, since it can be used as a fresh vegetable and serves also for drying and canning. Industrially and culturally it is far superior to wheat. It is a better stock food and it has many useful nonfood adaptations which wheat has not. It can be produced at less cost, and requires much less reserve for seeding. Not least, its possibilities in the matter of varietal improvement are much greater. In no single particular is wheat the equal of corn except as a bread-making material, and in this it far excels corn.

Accepting the experience of the past as demonstrating the necessity for bread, as showing that man will accept no substitute if bread can be had, the problem of a larger or an entire substitution of corn for wheat as human food narrows itself into an inquiry into the bread-making possibilities of corn. The writer discards from this inquiry all question of hot bread and all breads made with admixtures of eggs, milk, etc., as not pertinent to the inquiry.

The exigencies of the war, the needs of American and Allied troops abroad, and of the civil populations of Great Britain, France, and Italy, demand the utmost economy in the use of wheat and rye. At the very best the supply is not equal to the most urgent need. Substitution there must be and has been. America's allies have cut wheat to the bone. The United States must do the same. Every substitute or part substitute must be used to the fullest extent. This the Allies are doing and this America must do. Yet there is an irreducible minimum—bread must be; and there is no bread-making material except wheat. Fortunately, what may be called, for want of a better term, the surplus bread-making energy of wheat flour enables the skilled baker to use a proportion of other materials as a substitute, more properly an adulterant. A reduction in the quantitative extraction of offal in milling wheat effects the same purpose. Bread made with an admixture of such adulterants is the so-called war bread. The list of adulterants may be extended almost indefinitely, but principally it comprises flour ground from corn, barley, oats, millet, and other locally available grains, or from desiccated tubers and roots of from the latter boiled and mashed. A certain proportion of these adulterants can be used to take up the surplus bread-making energy of the wheat flour and the resulting bread, while less tasty than all wheat bread, in the emergency is entirely satisfactory. The proportion of the adulterant which can be used appears to be from one-fourth to one-third of the whole. From this fact it is argued that this proportion of the wheat flour can be conserved. It does not so work out in practice. Any proportion of wheat, even the whole, can be conserved by not using bread; but if bread be used, the proportion of the adulterant which a skilled and properly equipped baker may be able to use is not the measure of the saving for the whole country. The farmer's wife and the ordinary cook, with poor baking facilities, often forced to use dry and other inferior yeasts, can not make use of the adulterants to any extent. As a matter of fact, at present very few of them make any effort to do so, having found by experiment that it was impracticable. The adulterant responds to a war emergency, and that only to a limited extent. It neither solves the problem of bread nor points the way to its solution. We must cease to eat bread, in which case we would in all probability eat potatoes instead, or learn to make bread of the adulterants alone. The latter is the real problem, and it should not be beyond human ingenuity.

Perhaps no better light can be thrown upon the matter, at least in its beginnings, than to inquire what property it is that wheat possesses and corn or potatoes do not, or what agency is applicable to the former and not to the latter, by means of which a satisfactory bread can be made of one and not of the other.

Wheat and corn contain about the same food elements in about the same proportions and they have about equal food values. Results of hundreds of analyses prove that variations within the wheats and variations within the corns are as great as the average variations between wheat and corn. The elements are carbohydrates (starches, sugars, etc.) about 80 per cent, protein about 12 per cent, ether extracts (fats) about 6 per cent, and ash about 2 per cent. In adaptability to the human digestive apparatus corn and wheat are about equal, with whatever advantage there be apparently on the side of corn; yet, on the whole, claims of superiority as human food for either over the other have but little foundation.

The chemical elements of corn and wheat are so similar as to be almost identical, but the forms these elements take differ; in some respects, speaking economically, almost radically. For one thing wheat is rich in gluten and corn is very poor. As a human food the gluten of wheat has no superiority over the same elements under other forms in corn. It is the mechanical and not the chemical or food properties of gluten that are of importance. The sticky, mucilaginous nature of gluten is the property that wheat possesses, and corn, other grains, seeds, and potatoes do not possess, which makes the former the only available bread grain. But this is true only because man, prehistoric man in this case, has been able to find an inexpensive, easily procurable food, and tasty neutral substance, which, applied to the gluten and through the action of heat, produces the marvelous result of converting wheat flour dough when baked into bread. The secret of wheat bread is in the "raising." The immediate action of the escaping gases of yeast or other leavens on the moist dough is purely mechanical. They render the dough porous. The loaf is further swollen in the initial stages of baking through the action of the heat of the oven. The resultant is, however, something scarcely to be expected of mechanical action. The taste and flavor of the leavened bread is entirely distinct from unleavened bread, parched flour, or roasted wheat. In effect a new food substance is created by the action of heat in the porous dough. Beef, potatoes, barley, corn, buckwheat, or oats are more or less the same no matter how cooked, and so also is wheat, unless it be in the form of leavened bread.

Except in the form of leavened bread, many (one is tempted to say all) starchy foods, grains, roots, and tubers are better adapted and more acceptable as human food than wheat. The secret of wheat bread is leaven. This fact can not be too much emphasized. If, then, a leaven can be found for some of the other grains or for some tuber or root, will not wheat be supplanted? No doubt it will be, if the grain, the root, or the tuber supplies a bread equally acceptable with wheat bread, and in addition offers greater cultural advantages. Corn and potatoes, beyond any question, answer the second condition; but the first condition, that is unanswered and has been but little studied. We say a leaven for corn or potatoes, but there is no need that it be such. It may be anything, a substance, a process, or an apparatus that will accomplish the purpose of making good bread. Quite recently prizes have been offered in New York for the best bread to be made from the materials classed by the United States Food Commission as wheat substitutes. This list includes corn, barley, rice, oats, and others. The idea of those offering the prizes appears to be that the secret of no-wheat bread is to be discovered in some development of the baker's art. This is not impossible, although the writer believes it to be improbable. Of all that goes to make the problem of corn or barley bread the baker is about the only one who has heretofore given serious thought to the matter. He and all his predecessors have failed, so that from the baking standpoint alone it is doubtful if more than has been can be accomplished. The chemist should try, the miller should try, perhaps the farmer might help. The baker has done all that can be expected; now others must come to his assistance. But, one asks, do we want to supplant wheat bread? Even if some other good bread be found would it not be well to keep both? It is not a question of what one wants to do, but of what conditions will force one to do. If the new bread answers every requisite as well as wheat bread, can be produced at much less cost, and is available over larger areas of the earth's surface, including in the main the present wheat areas, then the material of which it is made must to a large extent supplant wheat.

Outside of human food, wheat, unlike corn, potatoes, barley, and oats, is but little used. There is but little need for it except to perform its one prime use—bread making. Wheat as human food has supplanted corn with two-thirds of the inhabitants of the American Continent, it constantly and rapidly supplants it everywhere. Almost as rapidly it is supplanting other grains—rice, manioc, and all other starchy foods; but only as human food. Wheat does not supplant corn. On the contrary the cultivation of corn increases much more rapidly than wheat cultivation. Before the war the people of the United States had almost ceased to eat matured corn, but they grew from three to four times as much of it as of wheat. In the battle between corn and wheat, corn had won on every field but one, but from this one it had almost entirely retired. Discover a way of making bread of corn and wheat will in all probability fall below barley, perhaps below buckwheat. Rye may be able to hold its own, but not wheat.

Corn is the economically superior grain, and it is produced in larger quantities. The figures given by the International Institute of Agriculture, Rome, for eight years, 1909 to 1916, inclusive, are: Wheat, 666,030,600 metric tons; corn, 651,520,700 tons. In 1910 the corn production exceeded the wheat, and again in 1912 and in 1914. Incomplete returns for 1917 indicate that the corn crop will exceed the wheat crop by 20 per cent or more. The institute's figures are confessedly incomplete. They include returns from about all the wheat, but by no means from all the corn producing countries. One hundred years ago the production of wheat was five or six times as great as that of corn. Corn, notwithstanding the war demands for wheat bread, has now taken its permanent place ahead of wheat, and this place it will hold even though it ceases to be in any degree a human food. This it has done because from the grower's standpoint it is the better grain and better fits the farm economy.

Corn was a tropical plant—that is, it originated in tropical America. Even yet half of Europe regards it a tropical plant, unsuited to any but tropical or sub-

*Bulletin of the Pan-American Union.

tropical regions. From South America, before the coming of the white man, corn had spread through Central America, Mexico, and the West Indies to the United States. Since it has spread over a large part of the globe. Corn statistics are compiled by the International Institute of Agriculture from Austria, Hungary, Bulgaria, Spain, France, Italy, Roumania, Russia, and Switzerland in Europe; from Japan and Russia in Asia; from Algeria, Egypt, and Tunis in Africa; from the United States and Canada in North America; from Argentina, Chile, and Uruguay in South America; and from Australia and New Zealand. These are States adhering to the institute and reporting. Corn is grown in addition in Portugal, Turkey, India, Serbia, Greece, Morocco, South and Central Africa, many of the islands of the Pacific, Mexico, the Central American States, Brazil, Venezuela, Colombia, Ecuador, Peru, Bolivia, Cuba, Jamaica, Porto Rico, Haiti, Dominican Republic, and other parts of the West Indies. It is not yet successfully grown in the British Isles or in northern Europe.

The cultural possibilities of corn are less well known than of wheat. Apparently we have very nearly reached the limit of what can be done with wheat, but by no means of what can be done with corn. In tropical South America, where corn originated, varieties of corn commonly grown require five months to mature. In the northern United States and Canada varieties of corn are grown that take only three months to mature. In all probability a variety will be found to mature in 80 days, and such a variety will be suitable for England and northern Europe. The same end may be attained in another way. There are great variations in the heat requirements for germination among the corns. A variety may be found to germinate at a sufficiently low temperature to make it suitable for these more northern regions. He is a venturesome man who says that corn may not sometime be grown wherever wheat is now grown. On the other hand, the areas in tropical lands (corn can be grown in all the Tropics) where wheat will grow must be very limited. Wheat has been developed through ages of experimentation and selection, and is now about what it was when Virgil wrote the Georgics. The gains of wheat in 2,000 years have been small, very small, as compared with the cultural gains of corn in one-fiftieth of the time. Corn is even now grown over much more than twice as large an area as wheat, and there is every reason to believe that this proportion will become greater. The United States produces over 80 per cent of the world's crop of corn and about 25 per cent of its wheat. In both grains it leads in economy of production. That is to say, it produces more of each grain per capital and labor units than any other country (except Canada on a par as to wheat). Its production per acre in corn is above the average of all producing countries, but its wheat acre production is below the average. England grows from 35 to 40 bushels of wheat per acre; the United States less than half this amount (under 15 bushels); yet the cost of production per bushel is less here than in England.

Production per acre is no test whatever of economy of production or of good agriculture. People who believe that all that is necessary to increase the bulk or cheapen the cost of grain is to make two plants grow where one grew before have but little knowledge of what it costs in labor and expense to make the second plant grow. Very often it is better to grow the second plant somewhere else. Some theorists and fancy farmers who farm for fun regardless of cost affect to believe that shiftlessness lies at the root of the low American acre production. These people, while no doubt they can produce 50, 60, or more bushels of wheat to the acre on land similar to that where their neighbors produce only 15, should know that the Chinaman can beat them at their own game. Yet China, with over 90 per cent of its population doing nothing but raise food, produces barley enough to live on, while the United States with a proportion of food producers only about one-fourth as great, raises enough for all and has a big surplus to export. This is to say nothing of the quantity and quality of what goes into the respective stomachs of American and Chinaman. The higher civilization demands extensive, not intensive, farming—a fact which our self-styled experts should learn.

Corn is the most economical grain we know. In the United States, where wheat and corn are both produced, two and a half to three times the measure of corn can be grown as of wheat. First-class land will produce from 80 to 100 bushels of corn, and the same land will scarcely ever produce over 30 bushels of wheat. Fancy farmers (and Chinamen) have produced 75 bushels of wheat to the acre, but, on the other hand, over 200 bushels of corn by the same methods (in South Carolina) have been produced on a single acre.

The seed requirments of corn are only about one-tenth the like requirements of wheat. Allowing for all losses through replanting, freezing, rot, etc., the actual seed requirement for the five-year period 1911-1915 was: Wheat, 90 pounds, 1½ bushels per acre; corn, 9.8 pounds per acre—a bushel to 5¾ acres. This saving in seed is of great value. On the other hand, wheat has some advantages over corn. It is better suited to new land; it requires less cultivation; it is sown in the fall and harvested in midsummer, so that sometimes it better fits in with an economy of labor distribution. Taking these advantages as an offset, corn is produced at from 50 to 60 per cent the cost of wheat.

Corn and hay are the bases of nearly all agriculture in the United States. Corn becomes a like base wherever it is cultivated. Our farming is built upon corn. The production of all food animals and their by-products, wool, hides, etc., depends upon corn. The farmers' work animals live upon corn and hay. Even the production of other grains depend upon the corn crop. Although we do not eat much corn we and a large part of the world would starve were it not for this most beneficient and valuable grain. The one thing needed is the discovery of how to make bread of it.—W. C. W.

Factors in Causation of Industrial Accidents

THE results of an investigation by Dr. H. M. Vernon of the factors concerned in the causation of industrial accidents are contained in Memorandum No. 21 issued by the Health of Munition Workers Committee.

Dr. Vernon's inquiries were carried out at four munition factories. At one data were tabulated for 25½ months, during the first three of which the total number of workers averaged about 6,000 and over 9,000 in the remainder of the time. Half to two-thirds of these workers were women, who were mostly engaged in making and loading time-fuses, though one-eighth of them were engaged on brass cartridge cases for small shells. At the other three factories the data were tabulated for 9½ to 13 months. At one of these, which made nothing but 6-in. H.E. shells, there were about 2,100 workers, two-thirds of whom were men at the outset, though by the end of the statistical period the proportion of men had dwindled to one-third. At the third factory, making only 9.2-in. H.E. howitzer shells, there were about 1,500 workers; to begin with four-fifths were men, but at the end not much more than half. At the fourth factory, making 9.2-in. and 15-in. shells, three-fourths of the 2,300 workers were men at the outset, dwindling to rather more than half later. The total number of accidents tabulated was 50,093 and of medical cases, 3,731.

Dr. Vernon's analysis of these accidents leads him to the view that speed of production is an extremely important factor in their production and often the most important factor of all; hence any improvement of factory conditions that increases the speed of production inevitably tends to a more than proportional increase of accidents. Output determinations at the fuse factory were made by measuring the excess electric power supplied to the various sections of the works, and were verified by direct enumeration of the articles produced. The incidence of accidents showed a qualitative resemblance to the output variations, and it was concluded that varying speed of production, and not fatigue, is the factor largely responsible for the day-shift variations of accidents with men. Even with women fatigue as a rule is only of moderate importance. The night-shift output followed a similar course to the day-shift output, but apart from eye accidents, the incidence was entirely different, being at its maximum at the beginning of the shift and falling gradually throughout the night to about half its initial value. The explanation given of this fact is that the night-shift workers started in a careless and excited state, and calmed down gradually during the night. The diurnal variations of accidents generally corresponded with the output variations, both rising to a maximum in the middle of the week and declining at the end of it. The monthly variations of accidents corresponded with output variations, for the accidents gradually increased about 40 per cent and the hourly output at the same time increased 30 per cent.

At the other factories, where shells were made, there was very little hourly variation in the speed with which the operations were performed, and in correspondence therewith the hourly incidence of accidents incurred by the day shift was fairly steady. The night-shift accidents dwindled rapidly throughout the whole night, because of the psychical factor.

The influence of fatigue on accidents to women was shown at the fuse factory when the operatives were working a 12-hours day, or 75 hours a week. The women's accidents were two and a half times more numerous than in a subsequent period when there was a 10-hours day, but the men's accidents showed no difference. The women were treated for faintness nine times more frequently than the men and were given sal-volatile 23 times more frequently, whereas in the 10-hours period they were treated for faintness and given sal-volatile only three times more frequently.

At all the factories the night-shift workers suffered fewer accidents than those on day shift, the average defect being 16 per cent. The reason was not that the output was smaller, as at the fuse factory it was distinctly bigger by day than by night. The origin was psychical, the night-shift workers settling down to a calmer mental state than those of the day-shift, and so becoming less careless and inattentive. The psychical factor Dr. Vernon declares to be one of the most important in accident causation. Indirect evidence of the detrimental effect of alcohol was obtained; the careless habit of mind can be diminished by stricter sobriety.

Accidents due to foreign bodies in the eyes were 7 to 27 per cent more numerous in the night shift than in the day shift, though all the other accidents were considerably less numerous. This was due to the artificial lighting, the excess of accidents being most marked in the worst-lighted factory.

Accidents in the fuse factory were found to be at a minimum at 65-69 deg. F., and increased rapidly at higher temperatures (*e. g.*, by 30 per cent at temperature above 75 deg.) and slowly at lower temperatures. In the shell factories it was found that the accidents increased considerably as the weather grew colder and diminished as it grew warmer. In one factory the women's accidents were nearly two and a half times, and the men's accidents twice, as numerous when the temperature was at or below freezing point than when it was above 47 deg.

Accidents being very largely due to carelessness and inattention, they could be diminished by preventing the workers from talking to one another in the shops. It was found that the women suffered twice as frequently as the men from sprains, and were especially liable to wrist sprains at the fuse factory, as they had not sufficient strength to push home the clamping lever of the lathes. The women at the shell factories suffered nearly four times more burns than the men, chiefly from hot metal turnings. The sprains could be reduced by alterations of machinery and the burns by protecting the hands.—*London Times Engineering Supplement.*

Ultra-Violet Transparency of the Lower Atmosphere and Its Relative Poverty in Ozone

THERE is strong reason to think that the limitation of the solar spectrum at sea level to wave lengths exceeding $\lambda 2,948$ is due to absorption by atmospheric ozone. To test whether similar absorption by ozone occurs in passing through the layer of air nearest to the ground only, arrangements were made to photograph the spectrum of a quartz mercury vapor lamp at distances ranging up to four miles. A cadmium spark was also used for distances up to 1,200 yards. The latter source of light shows strong lines right through and even much beyond the region of strongest ozone absorption, and is, therefore superior to the mercury vapor lamp, but practical difficulties stood in the way of its employment at greater distances than 1,200 yards. The experiments showed that the lower air is far more transparent to ultra-violet rays than the upper air if equal masses are considered. An approximate calculation shows that such absorption as does occur in the ozone region in the lower air might well be accounted for by the small dust particles in the atmosphere, and thus the present experiments afford no definite proof that ozone is existent in the air near the ground; but if such does exist it is demonstrated that the amount does not exceed a thickness of 0.27 mm. at normal pressure and temperature in 4 miles of air. It is quite clear that the air near the ground contains very much less ozone than the upper layers.—Note in Sci. Absts. on a paper by R. J. STRUTT, in *Roy. Soc. Pro.*

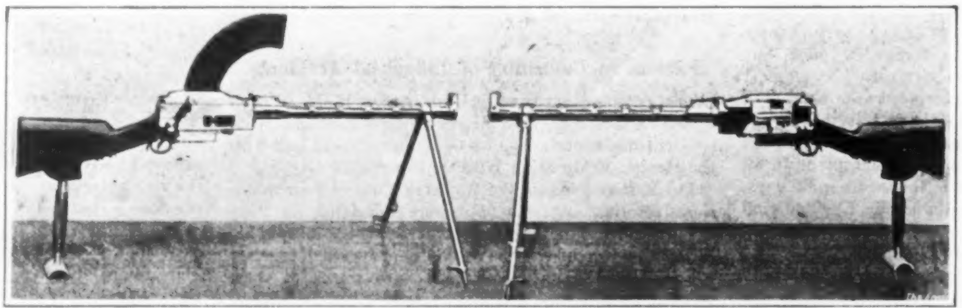
Sunflowers for Silage

EXPERIMENTS with sunflowers to determine their suitability for silage are being conducted in the western United States by the Bureau of Plant Industry, in cooperation with State experiment stations. There are indications that this crop may be specially useful in regions where the growing season is too cool for the production of large yields of silage corn. The experiments were begun in 1917 at Huntley, Mont., and Scottsbluff, Neb., and the first year's results led the investigators to extend the work to other points this year. In 1917 the yields of sunflower silage exceeded those of corn silage in the same fields from 50 to 100 per cent. Yields of more than 20 tons per acre were obtained under irrigation. Preliminary feeding tests have indicated that the sunflower silage may be substituted satisfactorily for corn silage, but directly comparable results have not yet been obtained in sufficient volume to justify a full statement as to the comparative values of the two feeds.—*Weekly News Letter*, Dept. of Agriculture.

The Madsen Automatic Gun

A Weapon for Which Great Efficiency and Certainty of Action Is Claimed

PUBLIC attention has been drawn in England to the Madsen machine gun, the invention of a Dane, which is claimed to be superior to any of the numerous models at present use by any of the warring nations; and the reason it is not now used is because, at the beginning of the war, it was possible to put another model into quantity production much sooner, and it is thought not desirable to lose time in making a change at present. As this gun discloses many interesting features it has been thought desirable to present the following description, which, with the illustrations, is derived from *The Engineer* of London; the description, however, applies to the gun as it existed two years ago. Since that time it is said to have been improved in many respects, but obviously no disclosure is made as to the changes; and as nothing has been made public of the details of the new American guns, no comparison is possible. In regard to the Madsen gun, it is safe to assume that the changes made during the last two years are only matters of detail, and that the principle is the same as in the gun here illustrated and described. The description by *The Engineer* is as follows:



Figs. 1 and 2—The Madsen Automatic Gun, with and without its magazine

The gun shown weighed just over 20 pounds, and there was no difficulty whatever in holding it to the shoulder for a time long enough to fire the contents of a magazine, but, as a matter of fact, the gun is self-contained with its own stand, which consists, first of all, of two legs *a*, Fig. 4, hinged to the underside of the fore part of the barrel casing *d* in such a way that, when the gun has to be carried, they can be folded up close and parallel to the casing, so that they do not get in the way, as is shown in the lowest view in Fig. 3. When it is desired to fire the gun these legs are hinged out away from the casing so as to form an inverted V—see Figs. 1 and 2 and the top view in Fig. 4. The stock is pierced some 6 inches from its toe with a hole for the reception of a tubular post, the bottom of which has a cross-piece to form a foot, and this constitutes a third leg for the gun, the height of which can be adjusted by means of a screwed sleeve. The extremities of the two front legs, which are remote from the hinges, are furnished with points *b*, so that when extended they get a grip of the ground. When these arrangements are made the height of the gun from the ground is about right for use by a man lying down. In order that it may be possible to fire the gun either from the sitting or kneeling position, or if for any other reason it is desired to elevate the muzzle of the gun to a greater extent than is possible by simply hinging out the legs, the latter are made telescopic, and the length may be practically doubled by unscrewing the foot a few turns, which enables an internal rod, to which the foot is attached, to be pulled out. This is done till a spring stop-catch which forms part of the rod, and which acts exactly as does the stop which holds an umbrella open, is uncovered and on being forced outwards by the action of its spring engages with the rim of the casing in which the rod slides and prevents the latter from being pushed back when it comes into contact with the ground. The arrangement used to connect the legs to the barrel case is in the nature of a universal joint, so that the gun can be moved from side to side and up and down or revolved round the axis of the barrel, within certain limits. Hence the aim may be altered without shifting the legs. It will have been gathered from the foregoing that the gun, the overall length of which is about 44 inches, is a handy weapon, which, as far as transport and aiming are concerned, is easy to manipulate.

We can now turn to technical details. The barrel *c*, which is some 23 inches long, including the chamber, is slightly greater in outside diameter at the breech end than at the muzzle. At both ends there is a length of some 3 inches where the metal is turned parallel, the intervening portion being given a gradual taper and having a number of rectangular channels machined in it for radiation purposes. The front end slides backward and forward in a bearing in what, for the want of a better term, we have called the barrel casing. The rear end of the sliding mechanism is carried by two projecting strips or feathers, which are free to slide in slots cut in the side of the casing. The whole of the sliding parts is thus only carried in three bearings, which reduces to a minimum the risk of bending even in the event of the casing being damaged.

The barrel casing is a cylindrical tube of metal which surrounds the barrel from end to end, and saving at the bearing we have just mentioned, is some ½-inch away from it. This casing is perforated with numerous round-ended slots, some ½-inch wide and a few inches long, the axes of which are arranged parallel to the axis of the barrel, and which are pierced at intervals round the circumference of the casing and along its length. The effect is to form an openwork cylinder round the barrel, the openings permitting of the radiation of the heat from the barrel to the atmosphere. The fore sight and back sight are fixed on the barrel casing and not on the barrel.

The breech mechanism casing is formed in two parts, a fore part *e* and a back part *ff*. The fore part is screwed on to the rear end of the barrel casing and the rear part is attached to the stock. The two portions are fastened together in the following manner: The lower portion of the rear part extends some distance underneath the fore part, and this extension is provided with a tongue f^1 which, when the two parts are pressed together, fits into a slot formed in the lower portion of the fore part *e*. On each side of the rear part and formed integrally with it are two projecting bosses, which form the bearings for the spindle *g*, which carries the firing hammer *h*, the recoil arm *j*, and the cocking handle *k*. These bosses engage on their outer diameter with slots cut in the sides of the fore part, and by so doing hold the tongue piece f^1 positively in its slot. The two parts are finally locked and held rigidly together by a screwed pin *l*, which is provided with a crank handle *m*—Fig. 3—in place of an ordinary screw head, so that the gun can be taken in half and the whole of the barrel and sliding mechanism withdrawn in two or three seconds without the use of any tools. The two portions of the breech mechanism case, when fixed together as just explained, form a rectangular box which is both longer and deeper than it is wide and which is open at the top.

Screwed to the rear end of the barrel is the breech block carrier *n*. This is also in the form of a rectangular box, longer than it is wide, and open at both top and bottom. The breech block *o* is pivoted on the pin *p* at its rear end in the carrier in such a manner that it can be rocked up and down vertically in it. A flange projecting downward from near its front end is furnished with a stout pin, shown dotted at *q* in the upper view in Fig. 4, which projects at right angles to the flange and is about a quarter of an inch long. This pin engages in a slot of somewhat peculiar shape formed in a rectangular plate q^1, which is fixed in an opening cut in the right-hand vertical wall of the front portion of the breech mechanism casing—see the lowest view in Fig. 3. This slot is shown diagrammatically in Fig. 5, which is not in any way drawn to scale. When the pin, which is represented by the circle A in the sketch, occupies the position indicated, the breech block is held in such a position that the firing-pin is immediately opposite the cap of the cartridge in the chamber of the barrel. It is, in fact, in the firing position. When the cartridge is fired the breech block, and with it the pin, are forced backward by the recoil of the barrel, and the pin strikes upon and slides up the inclined surface B and along the channel C till it reaches the end of the latter and falls on to the stop D, where for the moment we will leave it, delaying for the time being reference to its further motions. It will be evident that, as the pin forms an integral part of the breech block, the latter must follow the movement of the former. Hence, when the recoil begins the breech block first of all travels backward in a horizontal line for a short distance and is then lifted upwards. The effect is to raise it clear of the rear end of the cartridge, so that the extractor can come into play. Before referring to the action of the latter, however, let us endeavor to explain the working of the remainder of the breech mechanism.

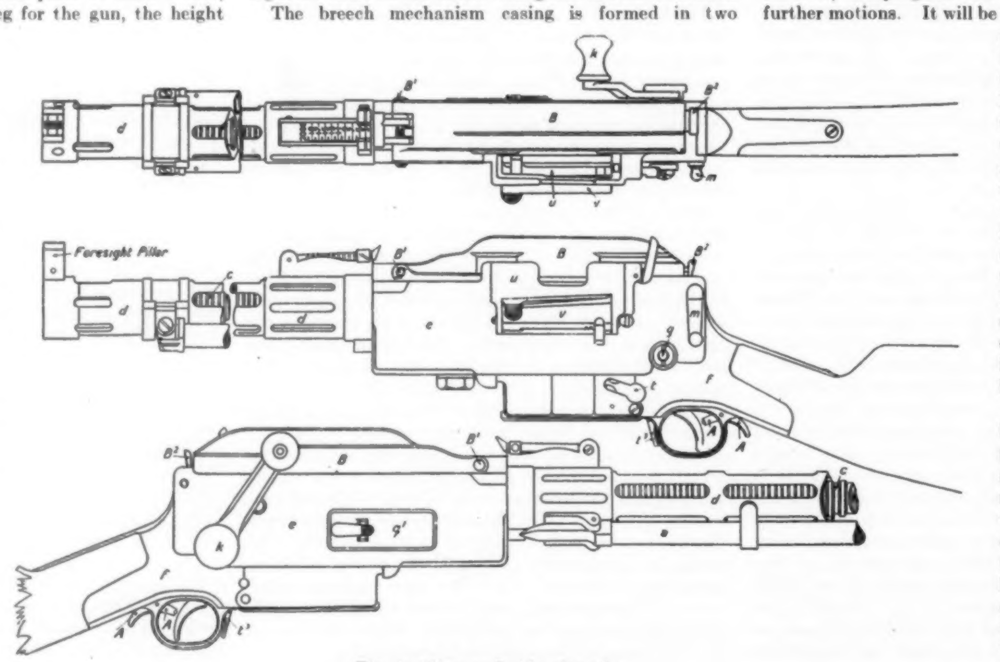


Fig. 3—Plan and side elevation

On the outside of the breech block carrier *n* at its rear end is fitted a detachable hard steel member furnished with a cam slot *r*, in which engages a projection j^1 on one arm *j* of what is termed the recoil lever. The latter is L-shaped, and its other arm *s* is mounted immovably on the spindle *g*. When the cocking handle *k* is drawn back the whole barrel and breech mechanism is drawn back with it. The head j^1 of the lever arm *j* projects sideways, and it is this part that engages in the slot, which is almost vertical, in the rear of the breech-block carrier. The arm *s* is pivoted to a spindle provided with a shoulder, against which presses a stout spiral spring. When the barrel recoils, and with it the breech-block carrier, this spring is compressed, and it is strong enough to return the barrel and all the accessory mechanism into the firing position as soon as the recoil is over. This is actually what happens when the gun is being worked and when each shot is fired—the barrel and the breech block carrier going backwards and forwards, first under the action of the recoil and then under that of the spring.

We can now return to Fig. 5. The pin A was, it will be remembered, left resting on the top of the stop D. As a fact, it actually rests there only for a very small fraction of a second when the gun is being fired automatically, for, as soon as the recoil spring begins to force the barrel and breech block carrier forward at the termination of the recoil, the pin travels along the stop D till it reaches the incline E, down which it is forced by the action of a hinged leaf spring o^1 that is always pressing on the edge of the breech block at the top, and is then taken horizontally along the slot F and up the incline G until it enters the horizontal slot from which it started and again takes up the position shown in the engraving.

We are now in a position to understand what is happening to the cartridges while these motions are taking place. The magazine which holds the cartridges is formed of thin plates and is in the shape of a quadrant, as will be seen from Fig. 1, which shows it in position on the gun. One end is closed and the other end is open, though the cartridges with which it is filled are prevented from escaping by the action of a spring detent, which is only disengaged when the magazine is properly fixed in position on the gun. The place where it is fixed is on the top of the left-hand wall of the forward part of what we have termed the breech mechanism casing. In order to receive it there is formed in the wall of the casing a rectangular box-shaped receptacle *u*, Fig. 3, which is large enough to receive one cartridge. The magazine is clipped in position with its orifice immediately over the top of this receptacle into which when the magazine is in place a cartridge is forced by the action of a spring, inside the magazine, that is put into compression as the cartridges are filled into it when the magazine is being charged. When the magazine is in position the axis of the cartridge which is first to be fired is parallel to the axis of the barrel and hence also to the side of the breech mechanism case and its bullet is pointing towards the barrel. The bottom of the receptacle or receiver is formed by an oscillating member *v* into a channel in which the cartridge is forced by the action of the spring in the magazine. This member, which is just the length of a cartridge and has its axis parallel to it, is formed with a channel, as shown diagrammatically at A in Fig. 6. It oscillates backward and forward on its axis like a watch escapement wheel, and as it does so forces the cartridge B through a slot C in the side of the breech mechanism case D on to the breech block E. The latter at this moment has had its front end lowered, since the pin A on its underside has been forced down into the slot F—see Fig. 5. Its front end, therefore, has been lowered so that the orifice of the chamber in the rear of the barrel has been uncovered. Were the gun to be held horizontally the cartridge would, when the breech block was in this position, have a tendency to travel down the groove which is formed in the top of the breech block toward the chamber, but reliance is not placed on the action of gravity, and the gun will work upside down or in any other position. What happens is that a special lever marked *w* in Fig. 4, which is operated by the forward movement of the breech-block carrier in conjunction with the stop w^2, but which, being pivoted on pin w^1, which is below the breech block, has a much quicker rate of travel than the latter, is made to come forward along the passage marked F in Fig. 6, engages with the rear end of the cartridge and forces it into the chamber. The cartridge is thus positively conveyed from the magazine to the barrel and at no moment is it dependent on its own momentum. A small fraction of a second after the cartridge has been forced into the chamber the pin A—see Fig. 5—begins to rise up the incline G and finds itself back at its starting point, with the result that the breech block is brought up to exactly opposite the rear of the cartridge. At the exact moment when this occurs the striking hammer is released and, under the action of its spring, comes forward, strikes an anvil *x* which abuts against the end of a spring-controlled firing-pin *y*, which runs from end to end of the breech block—see Fig. 4. The result is, of course, that the cartridge is exploded, and the barrel with the breech block carrier and other mechanism are forced backward.

When this occurs the forward end of the breech block is raised so as to be free of the end of the cartridge by the action of the pin A—Fig. 5—running up the incline B. The extractor mechanism then comes into play. This consists of two pivoted members *z* and z^1, which are in contact with one another and act in unison. They are both pivoted at the lower part of the forward end of the breech-block carrier, and when not in operation the extractor proper is held down out of the way so as not to prevent the insertion of the cartridge into the barrel. When, however, the barrel begins to travel backwards the extractor *z*, which is arranged vertically beneath the rear end of the cartridge, is forced upward, because its lower end encounters and runs up an incline formed at the bottom of the forward portion of breech mechanism casing, the upward motion being possible by reason of the fact that the pivot hole in the extractor is slotted. The effect of the upward motion is to cause a notch in the top of the extractor to engage with the rim of the cartridge in the chamber. Immediately this has happened the lower end of the other portion of the extractor mechanism, which is marked z^1, engages with another incline, and when this occurs a projection on its acts on the extractor in such a way that the cartridge is forced out of the chamber—this being possible since, as will be remembered the breech block has previously been raised—and is made to strike against a curved groove formed in a quadrant-shaped projection in the underside of the breech block *o*, so that it is expelled from the breech mechanism casing through a rectangular hole in the bottom of the latter. This hole is ordinarily closed by a hinged trap door, and we may here explain that even if the operator has forgotten to open this door before beginning to fire, it is opened automatically as soon as firing commences. In the lower left-hand view of Fig. 4 the cartridge case is represented as just having been forced out of the breech chamber, and with its rear end striking against the curved quadrant on the underside of the breech block.

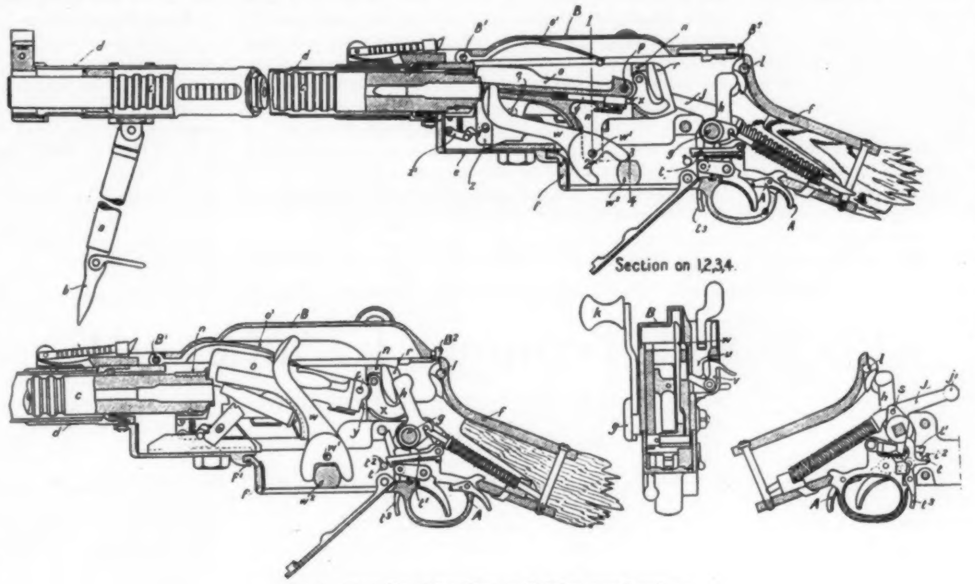


Fig 4—Details of loading and firing mechanism

Fig. 5

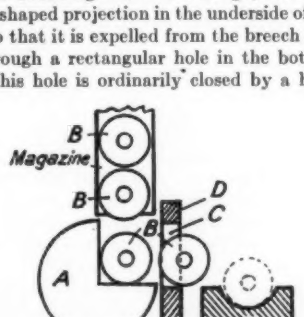


Fig. 6

The backward motion of the breech-block casing has various other effects. It brings about, for instance, the return of the lever *w*, which has forced into the chamber the cartridge just exploded, so that it may be ready to come forward and force another one in. Then, too, the motion, of course, compresses the recoil spring, thus storing up energy for firing the next shot, and it also compresses the firing lever spring and cocks the mechanism.

We must revert for one moment to the magazine and to the cartridge-feeding mechanism. It will be remembered—see Fig. 6—that, in order to feed a cartridge into the chamber the member *v*—Figs. 3 and 4—oscillates through the arc of a circle. As it revolves with a cartridge in its groove further cartridges are prevented from issuing from the magazine by reason of the curved shape of the member. On oscillating backward, however—and both forward and backward oscillations are brought about by and work in concert with the motions of the breech-block carrier—another cartridge is received into the groove from the magazine, which cartridge is, at the next oscillation, forced on to the breech block and from thence into the chamber, and the series of operations outlined above is repeated. Each magazine is constructed to hold 25 cartridges, but when the gun is working automatically or firing single shots only 24 are fired from each magazine, the last cartridge remaining unfired until another magazine is put into place. This arrangement has been made so as to render unnecessary the cocking of the gun as each successive magazine is fixed. It is only when the last cartridge has been fired and none remains in the gun that recocking becomes necessary before another round can be fired, and to fire the last cartridge special movements have to be made.

To describe in such a manner that they may all be understood the actions of the recoil lever, the firing lever, and the trigger is, even with the aid of the drawings which we are enabled to reproduce, an impossibility. All that we can do is to give a general indication of what certain things are done. To begin with, then, the gun can be made either to fire single shots like an ordinary rifle or it can fire automatically, when, with one man to manipulate the mechanism and to aim and another to remove the empty and clip on full magazines, as many as from 300 to 400 rounds per minute can be fired. One man unassisted can, we understand, fire up to 300 rounds per minute, including the changing of the magazines. When firing single shots the mechanism is comparatively simple, the striking hammer, which has been mentioned above, being released very much in the customary manner, so that it strikes on the anvil abutting on the rear end of the spring-controlled firing pin in the breech block. When it is desired to fire the gun in this manner a stop A is advanced toward the rear of the trigger so as to prevent the latter from being pressed back beyond a certain point. If, however, the gun has to be fired automatically this stop is withdrawn so that the trigger can be pressed back to the full extent of its travel. The effect of this is to disengage the single-shot firing mechanism entirely and to bring into play another set of mechanism, which is actuated by members working in connection with the forward arm of the recoil lever. In neither case can the firing hammer be released until the barrel has been pressed forward into the extreme position, or, in other words, until the pin *q*, which, it will be remembered, forms an integral part of the breech block and works in a specially formed slot, has brought the block into the firing position. The actual releasing of the sear from the tumbler of the firing lever is brought about, when the gun is working automatically, by the passage of a cam, actuated by the recoil lever, over the top of a member working in connection with the sear, and this does not occur until the recoil lever has reached the extreme forward point of its travel.

The gun is provided with two safety devices. One of these, *t*—Fig. 3—is arranged on the left-hand side of the breech casing and is provided with a small handle by which it can be rotated through a small angle, with the result that a catch on it, t^2—see the drawing in the right-hand bottom corner of Fig. 4— prevents the sear, t^1, from liberating the hammer *h*, no matter how hard the trigger may be pulled.

In the event of a damaged or distorted cartridge causing the mechanism to jamb during its forward or charging

stroke, when the gun is being fired automatically, the procedure in order to free it would be to open the door or lid B, which forms the top of the breech mechanism casing, and either to remove the cartridge or to assist it on its way to the barrel. As soon as the jamb is cleared the barrel will, of course, unless something be done to prevent it, continue to advance, under the action of the recoil spring, and on the completion of the forward stroke the cartridge will be automatically fired. So that this may not happen another safety lever, t^3, has been provided. As soon as a jamb occurs this lever is pressed, and its effect is to liberate the trigger mechanism from its cocked position, into which it has been put by the previous recoil, with the result that, although the barrel and its accessories are advanced to the furthest forward position, the hammer is not liberated and the shot is not fired. In fact the gun must again be cocked before firing can proceed. The cocking is, as will have been gathered, brought about by the handle *k*, which is provided with a hand knob. This handle or lever is on the right-hand side of the breech casing and it acts upon the spindle *r*, to which, it will be remembered, is fixed one arm of the cocking lever. The revolution of the handle *k* through a quarter of a circle in a anti-clockwise direction causes the barrel, with the breech block, etc., to be drawn back to the fullest extent, thus compressing the recoil lever spring and the firing lever spring and cocking the firing mechanism. This backward or cocked position is the normal condition of affairs. When single shots are being fired the effect of each explosion is to bring the barrel and the other mechanism backt o the furthest extent and hold them there until the trigger is again pressed, and it is the same when automatic firing is in progress at the completion of the discharge of a magazine full. It is only when the last shot has been fired and the trigger again pulled that the mechanism is forced forward into the advanced position, where it remains, since there is no further explosion to push it back again. The cocking lever does not, of course, rock backward and forward as the shots are fired. It may, in fact, when the rearward motion of cocking has been performed, be again pushed forward into its original position, in which it stands vertically, and in which it is held by the action of a catch.

We explained with regard to the breech mechanism casing that it was practically an oblong box which was open at the top. As a matter of fact, it is actually closed by means of a tight-fitting steel lid B, which is hinged to the forward end of the casing at B^1 and is held closed by means of a spring detent B^2, which embraces a catch on the top of the rear portion of the casing. This lid must be kept closed while the gun is being fired, for, hinged to its hinge pin and kept down by it in its normal position, is the leaf spring o^1, which presses, as explained above, on the top of the breech block and tends to cause the latter to hinge downward on its pivot.

It may be remarked in conclusion that, whereas, of course, the channels machined on the outside of the barrel do not afford sufficient surface for the entire radiation to the atmosphere of the heat generated when numbers of shots are fired in rapid succession, yet they do dissipate a good deal of heat, and then, too, the barrel and its breech-block carrier can be readily and quickly removed and replaced by another in about 20 seconds, so that, with two barrels the gun can be fired practically continuously, the hot barrel having time to cool while the other is being used.

Ports and Terminal Facilities—II*

Neglected Economical Problems

By R. S. MacElwee

[Concluded from Scientific American Supplement, No. 2223, Page 83, August 10, 1918]

The narrow covered pier accommodating only one ship and not over 1,000 feet in length is not so inefficient when it serves only as a transfer bridge. This is its function at New York. As there is no belt line connection by rail at New York, and as this service is done by the lighter, the berth opposite the discharging ship is left free for lighters. The freight is trucked across the pier from the ship's sling to the lighter.

Some efforts have been made to make the cross-pier movement by mechanical means. This effective system is satisfactory so long as the deck of the pier, the floor of the pier-shed, is kept free from obstructions, such as drays and railroad tracks. There is no place for railroad tracks on the usual narrow pier. It is too small as it is. So long as the pier serves as transfer bridge from ship to lighter there is really no need of rail connection.

With the introduction of the belt line connection from transit shed to railway system the question arises where to put the tracks on the pier. At one of the Bush piers the tracks are simply laid down the middle of the pier flush with the pier deck.

Cars nor not only difficult to load from the track level, but the pier deck is now cut in two. When the deck is divided by tracks it becomes necessary to have each half large enough to hold the entire cargo of a ship. The result is two transit sheds separated by the railraod traffic.

This has been done in the new Philadelphia piers. They are 300 feet wide and carry what amounts to two sheds separated by two railroad tracks down the middle. Goods when unloaded and classified are trucked across the deck of the pier, not to waiting lighters, but to waiting freight cars.

What has become of the lighters? They are too valable a piece of harbor equipment to fall by the wayside. The lighters, as at Hamburg, London, and elsewhere, have much to do. They handle less than carload freight to ships in stream, goods from local warehouses and manufacturers on the water front. Also, freight in less than fifty-ton lots to river barges.

The lighters must now lie on the water side of the ship and receive freight directly from the ship overside. Also, they may come alongside the pier after the ship has gone. Here the crane is a great advantage over the cargo mast or ship's tackle, and an explanation why it is so universally used at the best European ports, in particular at those ports where there is much lighter and barge traffic.

As soon as the lighters come into the pier slip as part of the day's work it becomes necessary to make the pier slip wider. Otherwise there will be no room for ships and lighters. The kind of congestion which ensues is seen at some of the old pier slips, only 125 feet wide. Lighters often become wedged in and miss the boat. Philadelphia is allowing 300 feet as the latest slip width.

A new pier at Cleveland, Ohio, shows a successful effort to connect the steamer with the railroad. The pier is 700 feet long by 300 feet wide. On either side, set back from the water's edge, are the pier-sheds, and in the center of the pier, back of each shed, is a pair of railroad tracks. In the center of the pier is a wagon road. However, with the width of the pier there could be added several times the length. A single narrow pier cannot be much over 1,000 feet in length without loss of efficiency and congestion. However, when the wide double pier is once started, with adequate rail and teaming roads in the center and with the freight movement crossing the shed to the tracks or teams in the rear instead of down the pier to the bulkhead, then there is no reason why the pier should not be extended to 3,000 or 4,000 feet. A pier of this type is nothing but the European quay system. A narrow pier cannot have tracks, trucks, or length. A wide pier can have all of these.

Commonwealth Pier, Boston, failed for lack of universal connections by rail. However, the middle should have been left for cars and teams and not covered for warehousing.

The question of *car tracks on the water side of the pier is completely involved in the question of freight-handling machinery*. The movement from ship to car and from car to ship is not frequent, and only in the case of certain heavy articles which require particular machinery. As the usual gantry crane in vogue is of three tons capacity, and seldom over five tons, it is usually necessary, even in the best equipped ports, to have a floating derrick come alongside and negoitate heavy loading.

In European ports packages of three tons are loaded directly from flat or gondola cars to ship just as at New York from cars to lighter.

The most recent works at Bremen show a wide pier-shed set well back from the water's edge, with floor level with freight car floors and served by great semi-portal gantry cranes of imposing dimensions.

At Hamburg the cranes are set every 100 feet along the quay wall. The railroad tracks at the ship's side are only for emergency. They are therefore set flush with the pavement in order to allow easy trucking across them.

When the freight comes out faster than it can be taken away by the stevedores it is never allowed to "hang," but it is set down at the most convenient vacant space. A ship tackle or casgo mast has a deposit area of eight to ten feet square; a crane, twenty to forty feet.

Four to six of these cranes work a ship, sometimes eight. Two can usually work at each hatch. The usual rate of discharge at Hamburg is 250 tons of general cargo per hour. The record of the *Saxonia* at Boston a few years ago was 190 tons an hour. The Liverpool Handbook cites the case of *The Lake Champlaney*, which discharged 12,000 tons of measurement cargo in forty-eight hours, which is an average of 250 tons an hour. The record at New Orleans for side port delivery is 130 tons an hour, but it cost seventy-five cents a ton. With cranes working for a record, they should do 500 to 800 tons per hour. The charge for the use of the public cranes at Hamburg is three cents a ton.

A similar layout, only smaller, may be noted at the municipal port of Stettin, on the Baltic.

Along the basins at Antwerp there is full crane equipment, but the sheds have been set well back, without any elevated platform for loading into railway cars. Some of the sheds have rail connection at the rear and some have not. There is plenty of room to maneuver, but the feeling of security from pilfering is not great. Some of the basins are lined with cranes, but have no sheds at all.

At Stavanger, in Norway, there are neither quays nor sheds, but there are tracks to allow the goods to be brought alongside the ship within reach of the ship's tackle and thus reduce handling and hand trucking to a minimum.

At Valparaiso, Chile, there is found the European quay and crane system of layout. The ports of South America represented improvements of one billion francs for the ten years before the great war.

It is often stated axiomatically that the pier-shed should be as close to the edge of the pier as possible. We have just seen that well-organized ports set the sheds back thirty to thirty-five feet from the quay wall. Again, both systems are right, depending on circumstances. Cranes have a longer reach, and there is also more room inland in the quay system. In the case of the pier there is so little room for deck space that the entire surface must be utilized.

A recent wharf at Jacksonville has gone even further from the water's edge than necessary. A semi-portal instead of a locomotive crane and the shed nearer the water's edge would have been better. However, when a smaller port does as well as this it should be congratulated and not scolded.

The new Galveston cotton warehouse wharf embodies much of the most approved and modern practice. The wharf apron carries two car tracks spanned by two semi-portal gantry cranes. Across the wharf are the freight car tracks. The shed is two stories of concrete, and both floors are served by cranes and freight cars. Locomotive cranes, as at Jacksonville, will occupy much more room than the semi-portal crane.

The cargo mast is a fortunate compromise. It is often argued that the reason the European ports use cranes is because the freight cars are open, and the Americans do not use cranes because of the prevalence of the box car with us. This is like saying that it is warm in summer because there is no snow. The fact that the cranes are used extensively is the reason for the prevalence of the open freight car. The use of the crane is to be found due to the fact that water transportation by barges makes unloading machinery on shore necessary. Also, a potent reason is the fact that the equipment is supplied by municipal authorities not looking to a large return on the money. Still another reason is the fact that more cargo passes over a municipal public quay per linear foot, and therefore the burden of the additional cost of the quay equipment is more diluted per ton lifted. A final reason is that the quay system has more room back from the water's edge.

The American machineless unloading may be defective, but there is no room on a narrow pier for cranes. The cargo mast is a successful compromise. On the pier edge masts carrying a girder at a height of seventy-five to eighty feet above low-water deck extend along the water's edge. A block and tackle with a line from a drum hoist on the pier to the hook is berthed to this girder. A ship's boom and hoist also operates another line to the same hook. There are three movements. Where the load

*Presented before the Engineers Club of Philadelphia, and republished from the *Journal* of the Club.

in the hold is attached to the hook, (1) the ship's winch raises the load; (2) the pier winch then starts to pull and the ship's hoist lets go; (3) the pier hoist then lowers the load. The movement is without lost motion and by the shortest possible route. The cost of installation is low, the saving is great. The cost of operating two hoists and two operators instead of one is greater than with the crane. For the sea ship the system is splendid, but useless for barges. Both the crane and the cargo mast operate at about forty cycles an hour.

It has been mentioned that at many ports where the connection with the interior by water has been well developed, cargo ships (bulkers) discharge overside in stream while moored to pile clusters or Duc D'Alves. For this no wharfage is charged at Hamburg. The expensive wharves charge fees on their general cargo which the low-grade bulk cargo will not bear. A ship carrying the major part of the cargo in bulk and a small part of it high-grade package freight will do better to stay at the mooring posts and have the freight lightered to her.

Rotterdam planned the port to accommodate water connection with the Rhine. Each new basin to be dug out of the land has been wider and with more rows of mooring posts. The first group of basins, in the town, built about 1600, were small. There were ten of them. The next four were built about 1879 and were much larger. The Maas Haven, opened in 1905, covers 150 acres and has three rows of mooring posts. A town was torn down to make room for it. The last great basin, the Waal Haven, not yet completed, will cover 700 acres with many rows of dolphins.

The system of overside discharge in stream has developed a particular type of cargo boat. The importance of the Rhine navigation may be gathered from the fact that in 1913 there was a Rhine fleet of 4,400 boats with a cargo capacity of 2,326,000 metric tons, and that 16,-300,000 tons going down and 19,000,000 tons going up the Rhine crossed the frontier in 1913. The total Rhine navigation was 76,000,000 tons. Barges as large as 3,500 tons leave Rotterdam. This shows what can be done with the Barge Canal and the Mississippi River.

At Hamburg only about half of the entire tonnage movement is negotiated in stream. The basins are, therefore, not entirely for mooring-post berths. A single row of posts to accommodate two rows of ships is sufficient. There are ten miles of such mooring posts. One of the most modern basins shows steamers loading and unloading at both quays, with lighters and barges alongside, and also two rows of cargo boats in stream discharging into lighters and barges. There is a heavy duty floating derrick alongside one ship and the pneumatic grain elevators alongside another.

Pneumatic elevators discharge grain overside into barges. Several elevators will work at one ship. The rate of discharge from ship to barge per elevator is seven to eight hundred tons per nine-hour day. Four machines will therefore transfer 3,000 tons, or 112,000 bushels per working day.

The harbors of the Atlantic seaboard at the present time are full of ships anchored and taking freight, in particular explosives, overside from lighters. In-stream loading is necessary in this case because of the nature of the cargo, as well as because of congestion at the piers. However, without protection and from choppy waves and the steamer swinging about at her moorings with every change of wind and tide, the work is dangerous, and the amount of harbor area required per ship is great. With the opening of the barge canal in-stream loading at dolphins should become a necessity.

The Warehouse.—The pier-shed is the reservoir to hold a shipload for one sailing. That is why we call it a *transit* shed. The warehouse system is the reservoir for the entire port for months and seasons. The present collapse at the ports is due not only to the fact that the transit sheds do not hold a full cargo, but to insufficient warehouse space to hold any overload of traffic. Mr. Geddes, a famous English expert in port and freight handling matters, said to me that the Antwerp authorities figured on a warehouse capacity of one and one-half times the cargo capacity of the port.

The Rotterdam warehouses are located near the water front. They are built in the place of a pier-shed a short distance back from the water's edge, within reach of long-arm jib cranes. Some are connected by a bridge spanning the marginal street.

In Brooklyn they use a telfer to establish physical connection between the transit shed and the warehouse across a marginal driveway and railway. Direct connection is an absolute essential. The warehouse must be completely connected with the water front and with the railway service.

One handsome set of London warehouses has only dray connection with the other means of transportation. Many of the Liverpool warehouses must cart every pound of freight to and from their doors. This is a fearful economic waste. But at Liverpool, as at New York, these conditions have been a bad heritage from pre-railroad times. On the other hand, the goods house of the London, Tilbury, and South End Railway is an example of the best intensive development of the modern railroad freight terminal in direct connection with the Tilbury docks, linking ships, transit shed, and railway net.

The Calvin Tomkins plan for the West Side of New York went a step further and applied the principles of intensive freight-house development to the marine terminal warehouse. The result is a freight warehouse with direct rail connection, in the lower levels, with the transit shed of the steamship pier by means of a short spur track, and with the truck railroads by belt line loading facilities for local cartage are ample. A similar plan of many-storied warehouse over the freight yard is nearing completion in Chicago for the Pennsylvania Railroad. The structure is not only modern in equipment and of enormous dimensions, but architecturally a marvelous edifice. The day of the open freight yards and the isolated warehouse is past. Urban freight terminal yards now occupy only warehouse basements. Cuppers' Terminals at St. Louis are a notable example. At the Bush Terminals the rail, pier, and dray coordination is accomplished.

A warehouse should be built with only eight or nine feet between floors. With low tiering not much waste headroom is required, but as many floors as are desirable are possible. Also, it is found to be more economical to hoist the cargo to the warehouse floor, not by elevators, but from the outside by means of long-arm cranes or "whip hoists."

The matter of warehouse location with respect to the wharf is important.

At Bremen, Stettin, and elsewhere the warehouse has been located directly back of the transit sheds and across a marginal driveway.

Goods intended for the warehouse are trucked across the shed deck to the rear, where the crane picks them up and sets them into the floor of the wharehouse where they are to go.

This seems very good in theory, but let us look at the situation more closely. Suppose a merchant keeps his stock all together in a warehouse, and a ship with a consignment for him docks at a wharf a mile down the quay. It will be necessary to cart the consignment a mile along the water front. The warehouse might as well be a mile inland. The carting is the very thing it was sought to avoid by locating the warehouses directly behind the transit shed.

Warehouses and Water-side Delivery.—The warehouse system which affords the greatest flexibility is *the warehouse group with water-side delivery* by lighter. At New York and elsewhere the lighter has grown to be of 600 tons capacity, and its service is to continue the journey of a train load of freight which has reached the end of its track. There is, however, a small, fast lighter which is not designed to supplant the railroad car, but to eliminate as far as possible the dray or truck traffic with the warehouse.

Goods brought alongside the warehouse in "lighter drays" are hoisted directly into the warehouse by electrically operated fall ropes.

This lighterage trucking system at Hamburg was an historical heritage. The "new warehouse town," opened in 1888, was built with access to the warehouse by means of a lighter canal. On the land side the warehouses face a street for drays and spur tracks as any other warehouse.

This system, which is developed at Rotterdam and at Hamburg, is an evolution, not an invention. Hamburg was a free and independent city-state from 1292 until 1871. Since then its extensive residuary state rights, of which the Free Port is one, make it an *imperium in imperio*. For this reason the port of Hamburg has been worked out and also paid for by the Hamburgers and by no one else. However, the English influence has been so strong that Napoleon called Hamburg, "Cette sale ville anglaise."

When the town was founded, in 1811, in the marshes of the lower Elbe delta, as in the case of Venice, for safety, it became a city of canals. Along these canals the Hanseatic merchants built their warehouses, with the front or office part toward the street and the warehouse overhanging a canal in the rear called "a fleet." The ships anchored in the Elbe.

An old map of 1796 shows a row or two of mooring posts and a log breakwater. Connection between ship and warehouse was by lighters which are poled or "staked." Lighters are still handled that way in London. The modern method is to tow them with oil-burning motors tugs operated by one man.

The first breakdown to this system came with the advent of the steam railroad. As early as 1835 the English engineer, Charles Vignoles, planned harbor improvements for Hamburg with rail connection from the quays and from the warehouses. It was considered an economic waste in 1835 to dray carload freight from warehouses to railway yards.

The first modern quay was opened 1866. The first municipal warehouse in the harbor fitted with rails and cranes was built in 1872. It was expected that seagoing ships would berth alongside the quay and discharge directly into the floors of the warehouse. This was soon found to be impractical, as, with few exceptions, all cargo must be spread out on a roomy shed floor, to be assorted according to marks. As ships increased rapidly in size the chances of discharging directly from ship to warehouse decreased.

With the incorporation of the state of Hamburg into the German Customs Union and the creation of a Free Port Zone of "customs outland" the entire warehouse system in the town became obsolete. The creation of the free zone of about 1,200 acres outside the customs barrier made free zone warehouses necessary. Accordingly 16,000 people were moved from an island near the heart of the business district, but within the Free Port, the buildings razed, and here a warehouse city was erected. The important part of it was that in order to retain the ancient system of lighter movement between warehouse and ship a lighter canal was cut through the center of the area.

The "lighter dray" gives complete flexibility from any pier-shed in any far-off basin or from a ship in stream to any one of the group of warehouses near the city. Draying, except for local consumption, has been almost eliminated. The lightermen perform the draying service at competitive rates in the neighborhood of two and one-half cents per 100 pounds. Lighters carry 40 to 100 tons.

The study of the peculiarities of a port's freight movement is essential. At the Bush Terminals the movement of freight is analyzed as this:

Thirty per cent is destined for the warehouse (by means of elevated truck, mule "lurry").

Twenty-five per cent carload railroad freight (usually car floated).

Twenty-five per cent less than carload railroad freight (usually lightered or car floated).

Twenty per cent dray for local delivery.

At Hamburg the half of the freight which does not go overside in stream for barge transportation on the interior waterways, but over the quays, has the following distributions:

Eighteen per cent by rail (carload and less than carload).

Twenty per cent dray to local consignee (or less than carload to railroad).

Forty-five per cent by lighter to warehouses or to river express barges.

Seventeen per cent goes into barges over the quay after the ship has left or over the water side of the ship at the quay.

It must be plain that the belt line does not eliminate the lighter. The belt line simply takes care of freight moving to and from the interior by rail. Even in railroad New York this is only half of the movement of the great Bush Terminal.

Within the free zone and likewise in the town are to be seen canal systems which are not of the usual harbor character. These are industrial sections with water-side delivery. Mr. Lindley, an English engineer, built one section by the cut-and-fill system of swamp-land reclamation. A private warehouse in Hamburg which has no canal side delivery is considered very inferior and commands only about one-half the usual rent. In hunting for a warehouse for elevator construction service station at Hamburg I found this generally to be the case.

Water-side Delivery for Industries.—The advantages of receiving coal by barge or lighter, not to mention other materials, are convenience and a large saving in expense There is great economic advantage of locating large industrial plants, in particular heavy industries, where both water and rail connections are possible. The French have recently awakened to the advantage which such location has given the Germans in the past. *Le Genie Civil*, in 1917, devoted several articles to the subject. Granted water transportation cheaper than by rail, the principle underlying the water-side location is that the low-grade raw materials are less able to carry the freight charges, and that the volume is greater than the finished product which can bear the charges.

At Frankfort-sur-Main the commercial port is completely equipped. The industrial terrain is located upland and has only land vehicles to serve it.

In the case of Neuss, that progressive municipality built the river port purely as an industrial harbor. Among other industries, the town succeeded in getting the International Harvester Corporation to locate on twenty-five acres. Municipal salesmanship is a fine art. Such a side-arm-canal port costs so much to build that if the price asked be based on a calculation of the cost of construction divided by the length of water front and then

the cost per unit of water front found by dividing by the depth of the plot, the proportion of cost per square foot of factory land would be prohibitive. No business could stand it. However, the rivalry of some forty river port towns along the Rhine is so great that the municipality pays the excess cost of the harbor and knows that the growth of the industry, with its increased earning power under conditions of complete traffic coordination, will more than offset the cost through the increased tax returns, increased population, and general civic prosperity.

The water front of a rail-bound Mississippi River town shows a sad contrast. Times are changing, however. The port of Duisberg is a coal center. In 1913 the movement of the port was 25,000,000 tons, mostly coal. It is equipped with sixty coal car tippers. Some of the basins are a mile long.

Not only the river port, but also the sea port, if the nature of the ground is such, can lay out an industrial harbor with side-arm canals to enable lighterage to supersede draying for many kinds of freight. Bremen has done this. The Vacuum Oil Company is one concern located in this industrial harbor.

The great problem in building the water connection is to diffuse the high costs of the harbor works over sufficient upland. This is a machine technical problem which will give our best engineers much opportunity to show their ingenuity. How can the benefits of water-front properties be extended as far as possible inland? is the question. Major Fordyce has utilized a chain-drive overhead trolley or telfer to connect cotton warehouses with the wharf. This has been a cheap and effective expedient at both Texas City and Mobile. The problem of moving general cargo is more difficult. There surely are some queer packages to be moved in general cargo.

At Detroit a certain flour mill has seen the advantages of complete water and rail connection. The wheat and other grain comes by boat in bulk from the Northwest and is loaded directly into a concrete elevator at the water's edge. Just back of the elevator and connected with it is a mill. At one side of the mill are spur tracks for the rail service. Given universal rail service by means of a belt line, and the coordination of transportation facilities is complete. Economic waste is reduced to a minimum.

The opportunity of side-arm canals and water-side delivery by lighter is offered whenever low marshy ground is reclaimed for industrial uses. It is about as easy to dredge the canals and use the spoil as fill as not to do so. A municipal port authority trust is the most satisfactory organization for land reclaiming and industrial and commercial port development. The scattered efforts of individuals cannot accomplish this. This was proven at Rotterdam, at Cuxhaven, and elsewhere in the '70's. An industrial port can be developed only when the area and the number of tenants are large. Newark Bay or Jamaica Bay is such an opportunity. The bay is far larger than the entire harbor of Hamburg. The development is by nature doomed to lighterage connection with the great cargo ships at the port of New York. Therefore, why not provide for lighterage streets, alternating with the dray and railroad streets? This will give the most economical connection.

The one great point to leave with you is that a port is not only a harbor, but includes terminal facilities. Terminal facilities include piers, warehouses, belt railways, lighters, and industrial as well as commercial harbors. The truly coordinated port is one where every part is connected with every other part; every pier with every trunk line; every warehouse with every pier; every trunk line with every ship in stream and with every industrial plant in the port area. This is what is meant by universal flexible coordination at ports with terminal facilities.

Modern Drawbridges Attain Great Weights and Spans

The recent completion of a very heavy bascule bridge over the Trent River, at Keadby, England, carrying the traffic of the Great Central Ry. to the Imminghan docks, supplements the list of notable drawbridges by the heaviest single-leaf Scherzer rolling-lift bascule yet built. There are longer single-leaf Scherzer spans, and both longer and heavier two-leaf spans.

The Keadby bridge consists of a leaf 160½ ft. long between main bearings and 63½ ft. wide. Including counterweights, it has a total weight of 6,325,000 lb. The structure has three trusses; on one side is a double-track railway line, and on the other side a 20-ft. highway. The center truss carries almost one-half the total moving weight, or 3,000,000 lb.

The longest single-leaf Scherzer span is the double-track crossing of the Baltimore & Ohio R. R. over the Cuyahoga River at Cleveland, Ohio. Its span is 200 ft. between main bearings. Span and counterweight total 5,250,000 lb.

The bascule span of the Tennessee River bridge at Market St., Chattanooga, Tenn., completed last year, is the longest and heaviest two-leaf rolling-lift span; it also has the remarkable feature of acting as a three-hinged arch when closed. The span between main bearings is 310 ft.; the deck has a 36-ft. roadway and two 6-ft. sidewalks. The total weight of leaves and counterweight is 9,000,000 lb. The designers call attention to the remarkably low weight of the machinery, there being only 46,000 lb. of machinery in all, and each leaf being operated by a single 25-hp. motor. The bridge has been successfully operated by hand power.

Bridges of the other bascule type most widely used, the Strauss trunnion bascule, have reached longer spans, and, except for the Chattanooga bridge, slightly greater weights.

The longest single-leaf Strauss bascule is one now being built to carry the St. Charles Air Line Ry. over the Chicago River at 16th St., Chicago, Ill. This will have a span of 260 ft. from center of trunnion to center of end bearing. Its weight will be 7,100,000 lb., including the counterweight. It has two through trusses spaced 32 ft. 4 in. between centers. The operating machinery will weigh 139 tons, including two 150-hp. electric motors.

The heaviest single-leaf Strauss bascule bridge, and the one of longest span now in operation, is that of the Baltimore & Ohio R. R. over the Calumet River at South Chicago, which was completed in 1914. The span is 235 ft. from center of trunnion to center of end bearing, and the weight is 7,600,000 lb., including the counterweight. It is a through bridge with two trusses spaced at 31 ft. 3 in. centers. For its operation there are two 140-hp. electric motors, and the weight of machinery is 125 tons.

The longest double-leaf Strauss bascule bridge is that carrying the Canadian Pacific Ry. over the U. S. Ship Canal at Sault Ste. Marie, Mich. This was also completed in 1914. It has a span of 336 ft. between trunnions, and is a through bridge with trusses spaced 20 ft. centers. The weight, including counterweight, is 7,500,000 lb. The operating machinery weighs 138½ tons, and includes four 40-hp. electric motors.

The heaviest double-leaf Strauss bridge, however, is the Palace bridge over the Neva River at Petrograd, completed in 1915. This weighs 8,400,000 lb., including counterweight. Its span is 208 ft. 8 in., and its width 91 ft. 3 in., with eight lines of through trusses. It carries a highway and electric railway. There are four 40-hp. electric motors. The weight of machinery is 455 tons. This includes machinery necessary to relieve the load of the counterweight from the counterweight trunnion when the bridge is closed, so that the bridge in this position will act as a three-hinged arch.

The longest vertical lift span is on the Great Northern Ry., crossing the Missouri River in Montana, 296 ft. long, center to center of end pins. The heaviest is the Willamette River Bridge of the Oregon-Washington Railroad & Navigation Co., at Portland, Ore., which with 220-ft. span has 4,300,000 lb. of moving weight. This bridge has two decks, the lower of which has a separate lifting arrangement by which clearance for ordinary vessels is obtained without lifting the entire span. Of ordinary lift bridges, *i. e.*, without separate lifting deck, the Pennsylvania R. R. bridge at Chicago with span of 272 ft. 10 in. and a moving weight of 3,000,000 lb. represents the maximum.

While not, strictly speaking, a lifting span, the Fratt or Armour-Swift-Burlington bridge over the Missouri River at Kansas City, Mo., should be mentioned on account of its great length of span, 428 ft. The lifting part here is the lower deck only; the truss span, which is set at a higher elevation, is fixed.—*Engineering News Record.*

Die-Casting of Aluminum Bronze

The advantages of aluminium as a die-casting metal are its low sp. gr., cheapness, and strength. Its chief drawbacks are high melting-point and shrinkage, weakness at high temperatures, and the tendency of the molten metal to attack iron. The high shrinkage can be reduced by alloying, and need not exceed about 1.4 per cent. Aluminium-bronze containing about 10 per cent Al does not give well-defined edges, but much better results are obtained if 1–4 per cent Fe is added. The mechanical properties may be profoundly modified by heat treatment; the temperature of the molten metal and die should be known, and the rate of cooling of the casting standardized. The dies are made of close-grained cast iron, as hard as is consistent with good machining properties. From 5,000 to 7,000 castings can be made before the die shows signs of deterioration.—Note in *Jour. Soc Chem. Ind.* on a paper by R. Hix and H. Whitaker, Inst. of Metals.

Parallel Jet High-Vacuum Pump

If a jet can be produced in which the molecules of vapor are moving in parallel directions with nearly equal velocities, then few collisions between the molecules of vapor would occur. Further, a gas molecule moving with the ject could enter it readily, but could not travel against the jet. The author has constructed pumps based on these principles, and entirely air-cooled. The nozzles used were of the divergent type common in steam-engineering practice, the throat being 0.24 cm. and the mouth 1.3 cm. in diam. The tube into which the vapor passed from the jet was from 2.5 to 5 cm. long and 2.5 cm. in diam., and beyond this was a larger chamber connected to the auxiliary pump. The jet disperses only silghtly, and will, if of a proper density, entrain the gas to be pumped even if the pressure of the gas is not more than a thousandth of the computed internal pressure of the jet.—Note in Science Abstracts on a paper by W. W. Crawford in the *Phy. Rev.*

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